The Language of Machines:

A Technical Perspective on Art, Women and Mechanics

by

Diem Lanakai

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Graduate Supervisory Committee:

Betsy Fahlman, Chair
Claudia Brown
Maura Reilly
Liz Cohen

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ABSTRACT

Social stereotypes in industrial countries have long regarded women as lacking the capacity for understanding the intricacies of machines, from appliances to cars. A major barrier excluding women from technology was the specialized language spoken by those in the industry. It is through my unique perspective as a female Automotive Master Technician that I explore the photographs, paintings, and prints during the interwar period between World War I and World War II created by female artists from a technical point of view. The First World War had artists such as Olive Edis who recorded female ambulance drivers while Dorothy Stevens, Henrietta Mabel May and Anna Airy showcased the skillset of the women machinists. During the interwar period Elsie Driggs rendered monumental structures while capturing the essence of the airplane all in the Precisionist style as Sonia Delaunay used her theory of Simultanism on the inner workings of the Spitfire airplane. For WWII, photographers M. Thérèse Bonney and Ann Roesner both snapped pictures of women operators of the lathe and drill press. Ethel Gabain's prints displayed women machining parts and Edna Reindel depicted women in shipyards. During the New Deal and WWII, Barbara Wright shot over 2,600 images of women. Finally, Laura Knight painted portraits of award winning women and to uplift the spirits of the public. These artists proved that women were more than capable of understanding this complex language of machines.

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CHAPTER 1

INTRODUCTION

Social stereotypes in industrial countries have long regarded women as lacking the capacity for understanding the intricacies of machines, from appliances to cars. There are always confidently instilled men around who are more than willing to explain it's function, even if this "information" is misinformation. My thesis topic is deeply embedded in my personal experiences as a female Automotive Master Technician which has given me an unusual perspective on works of art inspired by machines.[1] As a woman immersed in this mechanized world, qualifications such as Master Technician are far from a guarantee of respect in this area dominated by a sexually charged language. Often women are compared to machine parts or used as a namesake for equipment, and are rarely perceived as an equal with a qualified understanding of the instrument in question.[2] A woman in the industry to this day has to prove, numerous times, her knowledge and ability in the form of a mechanical dialogue developed by those who fabricate or repair machinery.

It is this language that was documented through photographs, paintings, and prints of female workers during the interwar period between World War I and World War II

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[1] The U.S. Census Bureau found of the 783,369 auto mechanics in 2019, only 2.12% are female. https://datausa.io/profile/soc/automotive-service-technicians-mechanics#demographics. As of Spring 2020, there are 63,618 ASE Certified Master Automobile Technicians in the U.S. ASE states they do not offer information about how many are women. https://www.ase.com/statistics

[2] Women reported about working in the automotive industry for 2017 as: Being tasked with lower-level assignments compared to their male peers- 65%. Unwanted sexual advances- 65%. Feeling unsafe at work- 25%. Carty, Wilson, Lutz, Ahmed, LaReau, Burke, Martinez and Charniga. ''This is how things are': Survey Finds Persistent Sexism in the Industry Stalls Careers and Leaves Women Feeling Unsafe." *Automotive News* 92, no. 6800 (Oct 23, 2017): 24.

displayed the expertise that these women learned and applied to machinery thus showing that women were more than capable of understanding this language. This experience allowed these new specialists to enhance their financial and social position.

These women artists portrayed the determination of the female workforce as they became adept at a wide range of jobs that require a strong mechanical skillset. Utilizing my perspective as a Master Technician in the automotive industry, it is through this unusual lens that these art works will be viewed as I explore how these female artists portrayed the skill of these brilliant women from a technical point of view. Without becoming bogged down in the theories of operation, I will dissect various artworks after the manner of Dorothy Levitt, "I will endeavor to explain everything in the simplest possible manner, without lapsing into confusing technicalities."[3]

To understand the mechanical frame of the reference, I find that the French philosopher Gilbert Simondon (1924–1989) captured in his letter to Jacques Derrida dated July 3rd, 1982 *On Techno-Aesthetics* the sensations that those who use their hands experience "a techno-aesthetic pleasure" that is stimulated when a wrench around a nut has broken the tight hold it has on the threads of the bolt and is free.[4] This same satisfaction is felt as a splined input shaft slides smoothly into place and the slight turn of a screw balances out the idle of an engine. This tactile action produces a sense of enjoyment that exists between the operator and the action; between the artist and paint; the musician and strings; and the technician and tools. Such a description sums up how

[3] Dorothy Levitt, *The Woman and the Car* (London: Ballantyne & Co. Ltd, 1909), 16.

[4]Gilbert Simondon, "On Techno-Aesthetics," edited by trans. Arne De Boever. *Parrhesia* 14 (2012): 3. This letter was later published by Derrida as special issue in the Papiers du Collège Internationale de Philosophie and was dedicated to Simondon.

those in the trades would explain the satisfaction that comes from finishing a complex project that required experience and training while engaging with specialized tools.

Learning a language littered with homonyms about automotive components and theory required my attendance in numerous courses, classes, seminars and practice sessions. There is a translation of this vernacular into a physical example between the body and mind such as the relation to what is torque and how it is applied as a concept and a physical movement, which is a vastly different experience for a woman. This language was instrumental in providing the proper background for determining component failure by first understanding the concern then utilizing this technical dialect during the various phases of the service repair process. When communicating with other specialists, technicians or engineers, a certain amount of jargon is used that has developed specifically from experiences within the industry such as how Service Manuals are written. As the automotive language continuously evolves, acronyms began replacing the full name of parts, producing many different names and some colloquial depending on who is discussing the repair and where they are geographically based.

Becoming articulate enough to discuss any mechanism requires more than a word list of automotive terms, but an understanding of how the device operates down to the fasteners in order to comprehend the new acronyms or the construction of a manufacture's label. Over many years I earned this knowledge through the required professional instruction from mentors who had manually labored on engines, motors and epicyclic gear trains. They provided me a viewpoint where literacy is only part of the equation when compared to the cognition stored in an expert's hands. In this crucible of the garage, I applied years of training and hard-won physical experience to my basic

understanding of the hydraulic principles of Pascal's law, electromagnetic theory, Ohm's law of electricity, laws of thermodynamics, gear reduction ratios, and the physics behind the internal-combustion engine. These accomplishments are monitored through a series of tests administered by the National Institute for Automotive Service Excellence (ASE), where I demonstrated my comprehension of the complex systems in an automobile through the ability to recognize elements within their diversity and demonstrate proficiency in servicing the various automotive systems.

After the successful completion of eight examinations based upon the different classifications of the vehicle's domains such as Engine Performance and Automatic Transmissions, I achieved the rank of Master Automotive Technician. I continued earning further certifications on the overview of general repairs, the structure of the exhaust system, an assessment on my familiarity with industrial principles required for administration, and lastly parts identification and coding all of which exemplify my knowledge of a vehicle and the automotive field. This background built solidly of experience within the industry up to the manufacture level led me to utilize this knowledge by disseminating it to students who wish to pursue a career in the automotive profession.

My background and credentials in understanding the theory and operation of machinery provides me with an informed interpretation of art produced by women that was created in the contexts of the industrial complexes originally dominated by men. Applying my deep understanding of machines, I intend to break down this language of the machine that had resonated with women artists who were fascinated both by the hard lines and smooth surfaces of machinery and how they functioned.

As significant numbers of women entered the factories after the onset of World War I in 1914, they learned to skillfully operate complex machines (often more quickly than their male counterparts). These women acquired this highly technical language from their wartime jobs, but were only begrudgingly given credit for their skillset. By demonstrating a command of this specialized vernacular, women mastered an understanding of machinery that their male co-workers considered beyond their intellectual abilities and continued to expand their expertise during the interwar period. After proving themselves capable of mastering the necessary technical information, a shifting power dynamic between female and male laborers in the workforce was solidified with the unfolding of World War II in 1939. Women artists discovered that the knowledgeable and skilled women who worked in mechanical trades were intriguing subjects for their paintings, photographs, and prints. These artists researched their subjects extensively and appreciated the proficiency the women exemplified. They took pride in their accomplishments in the industrial sector, even if the managers disapprove of these new women mechanics, though in truth they had no choice as the shortage of male workers meant that women had to be hired to replace them. A significant area of experiential learning occurred with a complex machine that soon became common place: the automobile.

In 1909 Dorothy Levitt published *The Woman and the Car a Chatty Little Handbook For All Women Who Motor Or Who Want To Motor,* in which she discusses important issues of how to dress while driving in addition to vehicle repair. As commercial production of cars began in 1895, Levitt sought to bring her trial by error knowledge to women who were unfamiliar with engines and who "may be afraid of a

mouse, or so nervous that you are startled at the slightest of sudden sounds—yet you can be a skillful motorist" which included the joy of self-reliance.[5]

An example of the prevalent male attitude towards women in relations to technology is showcased by Francis Picabia (1879–1953) an painter who completed *Portrait d'une jeune fille américaine dans l'état de nudité/ Portrait of a Nude Young American Girl* (Figure 1) in 1915. In the lithograph he compared a woman to a long slender spark plug body with a small head ending in an unfeasible long electrode without insulation for control at the tip. When compared to an actual spark plug, the head is long, the body squat and the tip small. Picabia emphasized a quick hot spark for a plug versus the controlled power a spark plug actually creates as his model for this portrait of Agnes Meyer (1887-1970) a sponsor and generous supporter of modern art.[6]

In Picabia's mind, equating engine parts with the female body was the best surrogate for understanding women. He carefully avoided the mundane for the elegant when sourcing the ad for a "Red Head" plug from *The Motor* found in the December 1914 issue, ignoring other uninspiring spark plugs.[7] Yet it was the combustion engine that introduced women to the vernacular of the machine, the physical experience of learning the art of engine repair as they traveled throughout the country. No longer were these behemoths issuing mysterious chattering, their clashing and roars a clamor. Instead, those noises turned into a symphony of meaning. With this technical aptitude, women

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[5] Dorothy Levitt, *The Woman and the Car: A Chatty Little Handbook for All Women Who Motor or Who Want to Motor* (London: Ballantyne & Co. Ltd, 1909) 15.
[6] William Innes Homer, "Picabia's Jeune fille Américaine dans l'état de nudité and Her Friends," *The Art Bulletin* 57, no. 1 (March 1975): 111-115.

[7] William Innes Homer, "Picabia's Jeune fille Américaine dans l'état de nudité and Her Friends," 115.

would position themselves as the logical choice for mechanical support to the allies when World War I began in 1914 and all the able-bodied men were conscripted into the war.

Among those who supported their country during the wars without taking up arms were artists, who received commissions from their governments as part of newly formed agencies such as the British Imperial War Museum, the Canadian War Memorials Fund and the United States Office of War Information to produce propaganda and news reports for civilians at home and troops abroad during both world wars. When Britain entered World War I, they employed artists like photographer Olive Edis (1876-1955), who captured photos of women maintaining ambulances and working in factories. These women provided a glimpse into the lives of these well-trained female mechanics. Painter Anna Airy (1882–1964) set up her easel beside these specifically trained female laborers. The Canadians were more robust in their recruitment for WWI as they hired many male and female artists, among them was printmaker Dorothy Stevens (1888–1966) who recorded the contributions of women towards the war effort in shipyards and the munitions industry. Additionally Henrietta Mabel May (1877–1971) painted scenes based on her industrial sketches as she followed women into these specialized spaces.

With the end of World War I in 1918, machinery began to fascinate American artists, particularly those who were Precisionists, a movement which flourished in the twenties and thirties. Artists who defined this style included painter Elsie Driggs (1898–1992) who was inspired by modern architecture, including bridges, as well as the contemporary mechanical marvel of the airplane. In Europe, Sonia Delaunay (1885–1979) grappled with advanced technology as she created a mural of an airplane engine and propeller mechanism in 1937 for the Paris International Exhibition of Arts and

Technology in Modern Life chronicling her understand of the mechanics behind this equipment.

Artists were called upon again at the start of World War II in 1939 as the various offices of war realize the value of documenting more than the events around soldiers and dedicated even more resources towards building a record of the women who contributed their support in the factories by providing hardware for those in the trenches. The British included printmaker Ethel Léontine Gabain (1883-1950) who studied the women working lathes and drill presses in grainy detail. The most notable painter in the Office of War Information was Laura Knight (1877–1970) a prominent artist who sought to include supporters other than nurses as she worked side by side with female machinists.

When the United States entered the war later, they followed in the footsteps of their allies as they brought on board female artists to record the efforts of women on the home front. M. Thérèse Bonney (1897–1978) an established American photographer in France who held a Doctor of Philosophy in Art, photographer Ann Rosener (1914-2012) whose works centered on the trades and little known but prolific Barbara Wright who photographed the U.S. during the New Deal and then for WWII.[8] Besides the government, privately held companies such as *Life* magazine sponsored artists to travel and record these talented women, like illustrator Edna Reindel (1894–1990) who integrated herself into the jobsites at the California shipyards.

[8] Sparse information exists for Barbara Wright and only in passing as part of an article on Annemarie Schwarzenbach, a Swiss writer and photographer. With over 2500 photographs in the Library Congress, this prolific female photographer has been over looked by history and further research should be conducted to fill in the gaps of her biography.

Recognizing these mechanically savvy women for their contributions during the world wars, artists in Canada, Europe and the U.S. rendered their accomplishments, while other artists added to the growing body of work centered around machines.

CHAPTER 2

THE FEMALE NON-COMBATANTS OF WORLD WAR I

When the First World War pulled men into combat the factories were forced to recruit replacements for the now vacant positions, a situation that led to women being hired for jobs from which they had been previously barred. New opportunities became available for women to make major contributions to the war effort at home and elsewhere. While women chauffeurs within modern industrial societies are now commonplace, when war broke out in 1914, few women occupied such positions. Being a chauffeur required women to possess training beyond basic steering or rules of the road. During that period, it was necessary that a driver also be mechanically inclined and capable of repairing the vehicle in the event of a breakdown, something for which few women had been taught.

Many female automobile owners were from independently wealthy families who had the time and means to learn about these machines.[9] These women were able to put to practical use this hard-earned skill by volunteering as ambulance drivers for the front as part of the Voluntary Aid Detachment (VAD). VAD volunteers were one of the many British women's groups who volunteered their skills and often vehicles during WWI that helped serve the military in hospitals as nurses or in supportive roles that included transportation driving.[10] In addition to women chauffeuring the wounded, they helped

[9] Georgine Clarsen, *Eat My Dust: Early Women Motorists* (Baltimore: Johns Hopkins University Press, 2008), 30.

[10] Clarsen, *Eat My Dust*, 33-34.

move personnel, supplies, and correspondences as further demonstration of their commitment and skills.

Olive Edis, who was the first woman commissioned by what became the Imperial War Museum and only the fifth person from Britain allowed entry into the war zone of Europe since the onset of hostilities, recorded the women's significant contributions to the war.[11] Edis was already an accomplished photographer before her government appointment as she had operated her own studio with her sister Katherine since 1905 where portraits were their main focus.[12] As Edis' success as a photographer grew, the Royal Photographic Society accepted her as a member in 1913. As an established British studio portraitist, the Imperial War Museum had her document the women involved in the war effort such as *Ambulance Drivers of the Voluntary Aid Detachment* (1919, Figure 2). Edis followed the women who had volunteered as drivers, a skill that was in short supply especially when considering commercially produced cars were only available starting in about 1901. Owners were responsible for their own repairs as automotive garages were rare.

The production line techniques of Ford's Model T began in 1908 providing a wider availability in the United States and England. It remained a luxury item, mainly

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[11] Michael Pritchard, "Exhibition: Fishermen & Kings: The Photography of Olive Edis," August 10, 2016. https://britishphotohistory.ning.com/profiles/blogs/exhibition-fishermen-kings-the-photography-of-olive-edis. The author recounts part of Edis's biography as well as the exhibition at Norwich Castle Museum in conjunction with the Cromer Museum.

[12] Liz Elmore, "Olive Edis Project," last updated November 16, 2017. https://oliveedisproject.wordpress.com. Norfolk Museums Service was awarded a grant to house and maintain the collection of Olive Edis that was offered by Edis' assistant, this website is part of The Olive Edis Project.

owned by the affluent as Britain saw roughly 3.5 vehicles per 1,000 people by 1915. The United States had ten times that number but these automobiles were for agrarian uses.[13] Those with the wealth to purchase a car were often doctors who used this equipment to make house calls while adding in their terminology of "trouble diagnosis" when figuring out the reason for the vehicle's inability to continue moving forward.[14] These early drivers learned thorough direct interaction with their machines and by trial and error how to maintain and repair them. Many terms used by medical doctors are still applied to automobiles today: arms, ball joints, knuckles, fingers, and the circulatory systems of oil and coolant pumped through the engine.

In the photograph *Ambulance Drivers of the Voluntary Aid Detachment,* Edis captured women in the midst of regular engine maintenance. Hood flaps are opened or removed, providing the women access to the heart of the ambulance, the engine. The vehicle in the foreground prominently displays an inline flat head 4-cylinder engine that is distinguishable by the arrangement of the overhead valve train. The first figure in the foreground is a driver with her back to the viewer. She leans on the fender, where her hands are out of view, dressed in a cap and long skirt with tall boots. She is assisting with this necessary maintenance to the valve train which consists of rocker arms, lifters, valves and pushrods that are accessible once the rocker cover located on the top of the engine had been removed.

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[13] Gijs Mom, *Atlantic Automobilism: The Emergence and Persistence of the Car, 1895-1940* (New York: Berghahn Books Inc., 2014), 8,69-71. The wealthy class found in Europe with the time and money to make pleasure trips was unique when compared to the U.S. prior to WWI were vehicles were used on farms.

[14] Mom, *Atlantic Automobilism*, 108.

The second figure opposite the first also leans on the fender and faces the viewer with her hand on the valve train as she grasps with her fingers a rocker arm which she checks for looseness. The skill of checking valve clearance is vanishing as the modern engine's use of hydraulic lifters automatically adjust without the cumbersome requirement of periodically checking the gap between the valve tip and rocker arm. Edis has encapsulated the amount of skilled knowledge these women possessed as drivers of today would be hard pressed, regardless of gender, to simulate what would have been considered routine maintenance during this era. With the automobile still a novelty, the diversity between engines from one manufacture to another was minute.

Most of the ambulances supplied to the allies during WWI were manufactured by James Cunningham, Son & Company of Rochester, New York. The firm had been established as a carriage maker, hence the term "horse-less carriage" which was adapted from when vehicles changed from being powered by live horses to a combustion engine.[15] Cunningham & Company built the ambulances on the platforms that used a 4-cylinder Continental motor with an overhead valve configuration that coincides with the photograph Edis captured of these women completing an inspection for rocker arm looseness.[16]

The attire required of women during WWI of long full skirts, presented a safety issue at odds with the amount of physical labor necessary to start these ambulances. The

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[15] Greg Merksamer. *Professional Cars: Ambulances, Hearses and Flower Cars*, (Iola, WI: Krause Publications, 2004) 32. Merksamer's book only examines the history of work vehicles and lacks any technical explain of mechanical terms or history of the automotive field.

[16] Merksamer, *Professional Cars*, 13.

long handles seen hanging down from the front of the radiator on both vehicles between the leaf springs that jut out past the bias ply tires are used to turn the engine over so it can run. These crank handles generated enough force to break arms or legs once the engine started running and required strength and stamina along with knowledge from experience of when to remove the handle. This is in stark contrast with electric starter motors that can crank the engine over with the slight turn of a key without out injury to life or limb after they were installed on Cadillacs beginning in 1912.

How women dressed while out in the field was seen in a derogatory light if they dressed in uniforms or clothes that hid their femininity while working for the VAD. Females who dressed sensibly for the environment were a topic of debate by the Women's Legion and the population at large that women were accused of "aping men."[17] There was a fear in society that these women would become 'masculine' as they lost their "maternal instincts" and would no longer adhere to the traditional standards associated with femininity but instead displayed immorality and lesbianism.[18] The culture during WWI viewed lesbianism as dressing up in men's clothes, learning to shoot and participating in military drills regardless of any romantic involvement with someone of the same sex.[19] Such an attitude about women who are interested or show aptitude for any occupation that is inherently male orientated is still a widely held belief in the

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[17] Margaret R. Higonnet, Jane Jenson, Sonya Michel and Margaret Collins Weitz, eds., *Behind the Lines: Gender and the Two World Wars* (New Haven: Yale University Press, 1987),118-121.

[18] Higonnet, Jenson, Michel and Weitz, eds., *Behind the Lines*, 121.

[19] Higonnet, et al., *Behind the Lines*, 121.

automotive field. Any women comfortable enough to display her mechanical ability, unless obviously partnered with a male, is often seen through this same lens today.

There is a second ambulance in *Ambulance Drivers of the Voluntary Aid Detachment*, and both women appear also in the process of performing another maintenance routine. A common check for vehicles in the era would be the level of engine oil in the crankcase. As gaskets during this time were typically made of leather, they were more prone to leakage than today's rubber-cork hybrids. The angle of the photo and the hood flaps in place obscures a view of the engine and the female driver who faces sideways has a cloth on the front fender and appears to be wiping down either a tool or a part. Tools are an integral part of any mechanical repair as they are especially designed for the removal of fasters found on a vehicle. As engines and the car chassis or body become more specialized when compared to the frames of horse pulled wagons, the importance of tools is seen by their inclusion in the photo of the cans near the first ambulance which contain all the necessary gear.

It is often said that 'clothes make the man' and in the trades, tools make the technician, having the right tool can mean success or failure of any repair. These ambulance drivers had to rely on the equipment they brought with them and their understanding of how the vehicle functioned as these women were far from towns and were relocated at a moment's notice. In order to maintain and repair these cars on the battlefield women became intimately familiar with them and with the terminology associated in order to converse with mechanics or other drivers when encountering a problem. This proficiency was captured by Edis who showcases the driver's knowledge

as the women are shown working under the hoods instead of being objectified and turned into hood ornaments.

Engine repair was only one area in which women increased their skillset; they also were extensively employed in the manufacturing sector. Operating large industrial equipment was decidedly a masculine occupation in addition to maintenance of any machine. Edis journeyed into the factories as she recorded the expertise women learned while working there as in *Members Of Queen Mary's Army Auxiliary Corps (QMAAC) Machine Room That Formed Part of the RAF Engine Repair Shops at Pont de l'Arche.* (1919, Figure 3). The British employed many different groups of women who helped industries with duties that originally were performed by men. In this photograph, Edis represents women working on lathes as they cut metal to create new parts. What makes this image unique is that Edis is showing not only women machinists operating the lathes, but also a female Quality Control Inspector.

The picture records many women and only a couple of men, yet all of the attention is on the central figure in a long light-colored coat clothed similar to the male figure on the far right edge. The difference in dress is immediately noticeable as are the double lapels and hint of a shirt and long skirt underneath her long light-colored coat. This is in contrast to the rest of the workers who appear in darker colored dresses that have short collars and hair in bonnets. This central female figure with a woman worker directly behind her is blurred, as are the other workers at her back. Edis brings into sharp focus the woman who is inspecting the machining process of the other female on the other side of the lathe. The woman is partially blocked from view by the drivebelts that come down from the ceiling to the lathe motor while the male Inspector who looks over

the operator's shoulder is unobstructed. The female Inspector is positioned at the back of the lathe as the levers to operate it are on the other side. Edis includes behind the Inspector another female machinist who is partially blurred, and stands in front of the controls for a different lathe where adjustment wheels, and levers are located. With this reference point, Edis shows what controls are utilized when running these lathes which the other machinist is running for the Inspectors.

The technical proficiency of the women running the lathes in this factory culminates with a female Quality Control Inspector or Q.C. Inspector. As the woman Inspector faces the lathe between her and the female operator, the Inspector's right hand rests on a tube responsible for spraying oil onto the part being machined to cool it and to lubricate the cutting bit. Her left hand rests on a pipe stand used to hold long lengths of bar stock at the end to help offset the weight as the opposing end is being cut. Neither of these components are currently engaged by the operator as she demonstrates her understanding of the lathe functionality to both Inspectors. Since an Inspector is responsible for the quality of the components that are coming out of the manufacturing process, they are required to be well versed in the procedures including how to use the equipment, proper techniques, and reading of precision instruments.

The image of the machine room bears witness to the many women who have become specialists at manipulating the equipment as well as the expertise that speaks to their accomplishments, specifically to a level beyond that of the other male machinists. A woman Inspector oversees a female machinist, and the photographer has effectively captured how her qualifications are demonstrated in her proficiency of the language of the lathe and respected for this knowledge. Edis sets the complex workroom of overhead

motors sending power down to the lathes by belts in the background as they are nothing but a prop of convoluted machines showcasing the hardware of levers and wheels that were run by these talented women. The women in the photograph are seen for their skills while bringing into prominence the Inspector who is an object of desire for her position gained by technical prowess instead of for her gender.

In addition to photographers, the Imperial War Museum hired multifaceted artists like Anna Airy who was simultaneously employed by the Museum, the British War Memorial Committee, and the Women's Work Committee.[20] Airy attended the Slade School of Fine Art where she consistently won scholarships during her entire five year course of study and afterwards was continually recognized for her talents as she was selected for membership into the Pastel Society in 1906.[21] She was then nominated for the Royal Society of Painter-Etchers in 1908, Royal Institute of Oil Painters in 1909, Royal Society of Portrait Painters in 1913 and finally in 1918 Airy was offered membership into the Royal Institute of Painters in Water Colors.[22]

Airy, along with Laura Knight, serviced as one of the few female artists for both WWI and WWII, and they received commissions from the Canadians and the British War Memorial Committee. The Imperial War Museum collected four of her works out of the

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[20] Sara Gray, *The Dictionary of British Women Artists* (Cambridge: Lutterworth Press, 2009), 13.

[21] Gray, *The Dictionary of British Women Artists*, 13.

[22] Gray, *The Dictionary of British Women Artist*, 13. Most of the biographical information for Airy was found in this extensive volume on women artists.

4,500 created by artists during WWI.[23] With women artist barred from the front lines, Airy entered factories and painted the industrial scene filled with machines as if it were a landscape. Setting up her easel in various factories, she painted en plein air, adjusting to the surroundings while she worked side by side with the machine operators as in *Shop For Machining 15-Inch Shells: Singer Manufacturing Company* (1918, Figure 4). Capturing each worker and their clothing while rendering the massive lathes and chain hoists they ran during the manufacturing of new shells, the women turned the steel while the metallic dust fell to the floor turning it a rust red.

Airy illustrates the smokey haziness of the atmosphere of the machine shop with the diffused light from the ceiling windows reflecting off the newly turned surfaces of enormous artillery shells. These shells were used by battleships and weighed 1,920 lbs., necessitating the need for hoists to move them about.[24] Hanging from the ceiling rafters in the warehouse space are steel bodied chain hoists used to maneuver the shells from the lathes and onto the wooden carts with steel wheels. Hoists scattered through the industrial space have a unique identifier of the chain wheel and block that Airy included showing that these were Yale Duplex Pulley Block hoists which were manufactured to hoist various amounts from 1 ½ to 10 tons with a pull of the chain.[25] According to the 140 year history of the Yale company, they had sales offices in Germany, England and France

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[23] Katy Deepwell, *Women Artists and Modernism* (Manchester: Manchester University Press, 1998), 72.

[24] Nigel Viney, *Images of Wartime: British Art and Artists of World War I* (Somerset: David & Charles PLC., 1991), 120.

[25] Columbus McKinnon. n.d. "The History of the CMCO Group" About Us. Last modified 2019. https://www.yale.de/en/company/about-us/the-history-of-the-cmco-group

starting in 1904, and as the inventor of the chain hoist in 1877, this made them the only company selling hoists at the time.[26] The ones Airy painted were considered new technology in 1896 as a housing would include a screw block that used a worm drive allowing the operator to lower loads weighing tons with utmost control. This hoist system is still in use today due to the versatility of allowing one person to move a large mass easily.

Airy's painting shows the carts with their geometric design as well as wooden cross supports that would creak as the steel munitions were slowly lowered down onto the cradles specially built for these housings. The large wheels were designed to carry the heavy loads while smaller front and back wheels provided better maneuverability for these bulky loads with minimum effort. Utilizing leverage and torque, the hefty shells could be moved from one location to another by anyone regardless of size or gender.

The machine shop that Airy documents includes details about how technological advances provided opportunities for women to operate the massive engine lathes. With size and physical strength no longer a constraint in the manufacturing process, women were able to use the lathes in an industrial setting as they learned the language of the workshop. It is necessary to understand this language inside a shop when communicating with other machinists or inspectors in order to provide clear and concise information about important day to day tasks. In the middle of the painting, Airy shows women inspecting the center of a shell, checking clearance before sending the housing off for

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[26] Yale & Towne Manufacturing Co. *Chain Blocks* Stamford, CT: Gillespie Bros. Catalogue from the University of Chicago library with no date in the brochure. Advertisement found in *The Monumental News* (8, no. 3, March 1896): 195, corresponds to one of the pages in the catalogue.

assembly. The mammoth engine lathes required training to utilize and a certain skillset for completing the shells according to specifications. Female operators working together would need to speak the same professional dialect so that they clearly convey necessary adjustments to the process. Working in teams this terminology allowed them to communicate with anyone on the industrial floor. Conversing in terms that only others in the field understand and comprehend provided a certain amount of prestige to the factory worker.

Airy's depiction of women machinists who are dressed with rolled up sleeves, hair tucked under bonnets next to these lathes brings into focus the apparatus's vastness and dangerousness. If clothing or hair were caught in the lathe, death or dismemberment would occur which was the same type of hazardous situation for those who handled chemicals in the munitions factories. Female operators standing at the lathes observe the steel castings as they shave off material as seen in the lower right hand corner of the painting of the shell interior. Various cuts were required in order to install a base plug with a tight fit once the shells were filled with different munitions materials depending on use.

Unlike Edis's photograph where males are in the background as foremen, only women are seen in the painting who are obviously performing the masculine tasks of transporting the substantial metal shells on and off the lathes as they are machined and then later measured. The drums of the lathes, architecture of the carts and chain hoists delineate this as a masculine space that women had successfully navigated as their skills proclaim the same dominance over machinery as any male counterpart. This view is at odds with Katy Deepwell who in *Women Artists and Modernism* claims that Airy's

command of the subject is limited to the ambiance of the factory with the exclusion of the women workers.[27] Deepwell misses the subtle clues that the artist brings into the painting of these strong women as the conditions they labored in are a testament to their aptitude. Airy had commented on the environment and its affects, such as how quickly her paint tried, while she worked alongside them.[28]

The crowded conditions of a factory are prototypical of the industry before it became regulated for worker safety in the 1970's in both Canada and the U.S.[29] An example of a cramped industrial area is displayed by Dorothy Stevens in her print *Munitions Fuse Factory* (1914 – 1919, Figure 5), which depicts Canadian factory workers. Dissimilar to the British, Canada began WWI with the idea of employing artists to produce documentation of the war and home front by creating the Canadian War Memorials Fund. The National Gallery of Canada under the CWMF was operated by chairman Sir Edmund Walker and director Eric Brown who officially hired artists. However, Brown initially only hired three women to document the war contributions in Canada through recruitment, yet Stevens contacted Brown directly about her interest.[30]

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[27] Deepwell, *Women Artists and Modernism*, 72.

[28] Catherine Speck, *Beyond the Battlefield: Women Artists of the Two World Wars*. (London: Reaktion Books, Ltd, 2014) 21-23.

[29] In the U.S. worker safety is regulated by Occupational Safety and Health Administration (OSHA) beginning in 1971 and in Canada by the Canadian Centre for Occupational Health and Safety (CCOHS) starting in 1978. I have taught courses where OSHA's history and mission are discussed. CCOHS information can be found at https://www.ccohs.ca/ccohs.

[30] Terresa McIntosh, "Other Images Of War: Canadian Women War Artists of the First and Second World Wars." MA thesis, (Carleton University, 1990) 34. McIntosh's MA thesis contains many sources directly from the Canadian archives and interviews.

The CWMF had specific goals for the collection as Brown offered Stevens a contract and set guidelines controlling the terms of her commission, which included requiring etchings be made on a large scale. Other stipulations included that the series was limited to twenty-five signed prints, and then the plate would then be destroyed. She was instructed to focus on the female worker in the munitions factories, foundries, shipyards and airplane manufacturing.[31] Under those restrictions, Stevens produced the etching *Munitions Fuse Factory* involving female lathe operators.

Stevens uses line quality to disrupt the space and create a sense of disharmony as the whole left side of the etching is composed of horizonal and vertical lines that intersect and intersperse at various points with each other. This sense of confusion when added to the throng of women along the lower half of the print provides the same sense of the tight conditions within which the operators toiled. The rows of lines receding from the foreground to the background at the top of the space are line shafts where large dark circular shaped pullies ride on and are suspended above the factory floor.[32] These shafts have one end attached to an industrial motor located deep in the warehouse space which transferred power through the belts down to the bench mounted lathes. The whirling belts and spinning pullies would create a dissonance when combined with metallic swishing

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[31] Laura Brandon, "Canadian Graphic Art in Wartime," *Canadian Military History* 19, no. 3 (2010): 45-46. Also McIntosh, “Other Images Of War: Canadian Women War Artists of the First and Second World Wars.” MA thesis, 27.

[32] Louis C. Hunter, and Lynwood Bryant, *A History of Industrial Power in the United States, 1780-1930: Volume Three, The Transmission of Power* (Cambridge, MA: MIT Press, 1991), 137. Hunter explains shafting in the 1890’s with the rise of steam power and the complexities found with shafting.

noise from the cutting bits of the lathes as they remove material from the metal fuses adding a chaotic sound to the already physically crowded conditions.

In her print, Stevens has recorded a gear reduction principle of a large pully driving a small pully in the lower middle center section of the image. The smaller driven circle with a belt wrapped around it just behind the seated female worker reflects the law of reduction as this belt drives the lathe at a high rpm or revolutions per minute. The large drums in the ceiling will increase the speed of the smaller pully attached to the lathes on the benches based on this theory. The belts and pullies run freely in this image without guards as this scene is prior to any safety standards for employees, creating noise and a hazard for those working near them. Counteracting the danger the speeding belts pose, the women are seen wearing head coverings with hair tucked back and away from the running bands. Workers throughout the etching are shown with sleeves rolled up to the elbows, keeping them away from the belts and rotating lathes. With the workers side by side, there is the danger of a sleeve or hair becoming caught in the bands and injuring the operator. The cacophonous noise of the shop is effectively reproduced by Stevens through the use of line and then space for the crowded conditions.

Since fuses for munitions are located at the tip of the shell body, and are the smallest part of the munition, they are components that could be turned on small lathes. Their cylindrical body with a cone which was larger than base at one end is a simple design that could be cut quickly. The fuse tips are made of a soft metal such as brass or lead, which would require finesse as they are machined to exact tolerances allowing the

fuse to slide into the cavity located at the conical end of the shell.[33] Stevens showcases all women lathe operators who work without a male supervising them as noted in Edis' *Members Of Queen Mary's Army Auxiliary Corps (QMAAC) Machine Room That Formed Part of the RAF Engine Repair Shops at Pont de l'Arche*. These female machinists are shown utilizing their skilled labor for producing fuses proving they are fully capable of running complex machinery minus exhaustive directions from men of the industry despite the congested and clamorous shop conditions.

Worker safety was the farthest from employer's minds as demonstrated in the painting *Women Making Shells* by Henrietta Mabel May (1919, Figure 6) where women in long dresses are portrayed assembling munitions and machining metal in close quarters. Where Stevens sought out Brown to contribute towards recording the civilian contributions to the war as part of the CWMF, Brown approached May as she had established a reputation as a distinguished Canadian painter.[34] May had studied with William Brymner at the Art Association of Montreal and was offered a scholarship to continue her studies. From there she embarked on a trip through England, Scottland, Belgium, and Holland with fellow painter Emily Coonan where their studies led them to France. In Paris, May was exposed to the Impressionists, Monet, Renoir, and Matisse who would have a profound impact on her work with their rendering of light and color through loose brush strokes. Bringing this style back with her to Montreal, May

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[33] Ian V Hogg, *The Illustrated Encyclopedia of Ammunition* (Secaucus: Chartwell Books, 1985), 47.

[34] Speck, *Beyond the Battlefield*, 34.

facilitated establishment of Impressionism in Canada and then joined as an Associate of the Royal Canadian Academy.[35]

May was one of four female painters commissioned by the CWMF and one of three women contacted by Brown since Stevens sought out Brown herself.[36] With the losses at the front, the Canadians attempted to boost morale by showcasing women in factories who assisted in manufacturing to support their forces.[37] Brown suggested that May visit the munitions or airplane workshops to gather material for a larger work and as a CWMF artist she was able to secure a permit for access to Northern Electric Plant in Montreal.[38] From September to December, she spent her time in the plant sketching, making color studies, and other larger works which ultimately led to a commission of *Women Making Shells* as a seven by six foot canvas.[39]

May was exposed to the same working conditions as those women who manufactured munitions, and where she worked was crowded, deafening, and dangerous. She recorded the hectic and congested conditions in which the women labored as seen by the upper left part of the painting where a dark cluster of wheels combined with a chaotic

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[35] Colin S. MacDonald, *A Dictionary of Canadian Artists.* Vol 4*, May, H. Mabel* (Ottawa: Canadian Paperbacks LTD., 1967), 1156-1157.

[36] Maria Tippett, *Art at the Service of War: Canada, Art, and the Great War* (Toronto: University of Toronto Press, 2013), 28-30.

[37] J. L. Granatstein, *Hell's Corner: An Illustrated History of Canada's Great War*, 1914-1918 (Vancouver: Douglas & McIntyre, 2004), 40, 137. Granatstein reviews WWI from start to finish of the Canadian troops covering politics, strategy, training, personal accounts and statistics.

[38] Speck, *Beyond the Battlefield*, 34.

[39] McIntosh, "Other Images Of War: Canadian Women War Artists of the First and Second World Wars," 25.

combination of chain hoists, bands, counter and line shafts which together comprise the millwork for powering the factory.[40] Shop lamps hang down to the middle of the space illuminating the workers below while keeping the jumbled mechanisms above in the dark, hidden in the canopy of wheels and hoists used to move heavy materials. A trio of women in the lower left quadrant where two figures with short hair in the foreground are packing the shells on a bench with a hand press. Behind them is a female in white with her hair hidden under a cap who is holding a bluish rectangle of an electric control box that activates the hoist for lifting substantial items. Across from her is another woman, also in white with a cap, bent over maneuvering the other end of the load with one hand. Directly behind these figures producing another triad is a male lathe operator wearing a green vest with sleeves rolled up as he runs a lathe where the flapping belt which drives it disappears into the mass of whirling pullies. Laboring in close quarters, both genders are seen performing identical tasks without the division of certain activities labeled as "women's work."

Drive bands drop down from the ceiling all across the shop, powering the various lathes run by men and women. Before the onset of WWI the majority of industries had converted from steam and internal combustion engines at the factories to a centralized electrical station that produced power for the equipment at various locations.[41] May included in the background against the golden electric lit wall of the factory, the essence of manufacturing, machinery. Two transmissions or electric motors distribute power

[40] Hunter, and Bryant, *A History of Industrial Power in the United States*, 115.

[41] Hunter, and Bryant, *A History of Industrial Power in the United States,* 139, 242.

throughout the shop as long brown straps radiate from these devices and attach to the end of a line shaft which in turn transmits power to the various lathes connected to them.

Another apparatus for running the equipment is found across the back wall where another shaft with belts is seen stretching down to the floor. All this millwork required adjustment with the correct tension and alignment. Otherwise the bands could break if the tension was too tight, or fly off if out of adjustment flailing anyone within reach. Since the machinery in the factory is in fact electric, this clashed with the observation made by Maria Tippett, author of *Art at the Service of War: Canada, Art, and the Great War*, that there is smoke in the workshop diffusing the atmosphere. None of the machines depicted would produce smoke during normal operation, thus any haziness in the factory would have been caused by the thinner than paper metal filings from the lathes floating in the air, providing an illusion of smoke to the untrained eye.[42]

The belts driving the lathes are rendered in browns with the drums at the lathes in a dark tan and gray as they turn the machinery on the shop floor. In the left of center of the painting a lathe is handled by a male operator in a white shirt and green vest with one hand on an adjustment wheel and the other locking down the material with a band positioned next to him. Across from the green vested man and to the right wearing an off-white dress and hair covered in a similarly colored cap with one hand on the lathe lever is a female machinist, also working perilously close to a spinning strap.

At a bench located in the lower right of the painting is a woman in a blue dress who slides a fuse tip into a shell body working next to a woman in a tan dress. On her left in brown is another female also in a long dress moving the munitions between the bench

[42] Tippett, *Art at the Service of War: Canada, Art, and the Great War*, 73.

and floor. Behind both women standing at the bench is a man in dark clothing and hat who is wheeling a cart of shell bodies, distinguishable from those on the table as they lack the cone shaped fuse tips. Equal division of labor is what May renders in her painting, and with the close quarters it is impossible to miss the mixed gender crowd who are running lathes as they produce parts for the munitions as others are moving shells, and assembling the components for the war arsenal.

By the end of WWI most of the world had been exposed to technology that had become incorporated in nearly all facets of day-to-day living. Yet jobs for the tech savvy women disappeared as factories reverted back to employing men as they returned home. War torn nations required reconstruction of their infrastructure which enthralled artists who were mesmerized by these engineering feats of the modern era as they incorporated the machine into their practice as the new mythos.

CHAPTER 3

THE INTERWAR PERIOD: ELSIE DRIGGS AND SONIA DELAUNAY

Elsie Driggs and American Precisionism

With the end of the Great War in November 1918, there was a brief reprieve before the world was consumed by another global conflict in 1939. During the interwar period Europe concentrated on rebuilding its economies while the U.S. advanced as an industrial leader on a worldwide scale. The American investment in technology changed manufacturing into a modern marvel of machinery. In reverence to the rise of these uncluttered, clean and precise engineering spectacles artists sought to convey these designs that focused on sleek lines and hard illumination. With their talent, artists in the urban centers of the country birthed a movement that reflected the age of machines, Precisionism.

The artists involved were loosely connected by style and subject matter, though many never met. They were captivated by the modern industrial landscape creating works devoid of human figures and focused solely on the industrial forms and when reviewers wrote about this style, they constantly applied the termed "precision".[43] It was in 1927 that this group of artists who enjoyed the promise of modern industrialization were dubbed the Precisionists by Alfred H. Barr, then associate professor at Wellesley College who would later become the Director of the Museum of Modern Art.[44] One of the artists

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[43] Constance Kimmerle*, Elsie Driggs: The Quick and the Classical* (Philadelphia: University of Pennsylvania Press, 2008), 14. The author includes other contemporaries of Driggs who were also working in the Precisionist style.

[44] Gail Stavitsky, et al., *Precisionism in America, 1915-1941: Reordering Reality* (New York: Harry H. Abrams Inc., 1994), 21-22. This is a good overview of the movement yet little of Driggs was included.

classified by Barr was Elsie Driggs who quoted D.H. Lawrence when discussing her paintings, "Since churches are all museum stuff, since industry is our business, now then let us make our places in industry our art… Art should interpret industry as art once interpreted religion."[45]

Driggs was prepared for the arts at an early age, her mother attended art classes while pregnant hoping to produce an artist. Driggs enrolled at the Art Students League in Manhattan and while there, she took a trip to Italy and was introduced to Piero della Francesca. His renderings of form and composition had a powerful impact on her and she admired his, "desire for structure and order, for simplicity and strength."[46] Driggs recalls one evening as a child when her father, an engineer and inventor, had shown her the flames from the steel plants that had dominated the horizon of Pittsburgh. She was haunted by this image and returned to complete studies of the mill, but Driggs was disappointed to find that the Bessemer steel-making process was discontinued.[47] She did complete sketches for a painting *Pittsburgh* (1927) which was her first rendering of machinery in what became known as the Precisionism style.[48] Beginning in 1924, Driggs was represented by the Daniel Gallery of New York where her works were displayed

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[45] Kimmerle*, Elsie Driggs: The Quick and the Classical*, 129. This quote is from D.H. Lawrence's *Women in Love* (New York: Knopf, 1992 ed.) According to Kimmerle this book was not commercially printed until 1933 but was available privately in 1920. Driggs knew the author through her art instructor, Maurice Sterne.

[46] John Loughery, "Blending the Classical and the Modern: The Art of Elsie Driggs." *Woman's Art Journal* 7, no. 2 (1986): 23.

[47] Kimmerle*, Elsie Driggs,* 31.

[48] Kimmerle*, Elsie Driggs,* 14, 30-33.

alongside other Precisionists artists, like Charles Sheeler, Peter Blume, Charles Demuth, Preston Dickinson, and Niles Spencer.[49]

In the *Queensborough Bridge*, (1927, Figure 7) Driggs revels her admiration for the monuments of New York's industrial age. She captured the distinctive formal character of the bridge using polished lines, allowing the framework and beams of light to dominate the space. Removing the human element as a focal point of the artwork, Driggs depicts the rays that break through the dreary clouds, highlighting the center as they divide the expanse and illuminate the burnt orange smokestack on the right banding it with yellow. The eye is drawn to the brightly colored smokestack of industry creating a border that contrasts sharply with the darkened sky at the top.

The spiked head of the bridge is the apex of the structure, forming a contemporary pyramid which stands proclaiming its dominance. The brown girders are the strength of its limbs that are grounded in the horizonal bands of the formation's thoroughfare. Underneath the girders is a cement pier grounding the assembly in the center of the lower portion of the painting which provides a glimpse of the water the bridge spans with a distant New York skyline in the lower left. Along the bottom three dark shadows are cast from the rays that mimic the bright bands of the smokestack on the right. Highlighted in the sunbeam is a spiral stair case where Driggs captured the play of light as she painted the hard lines of the structure bereft of people, which was typical of a precisionist, and instead focused on the serene beauty of the architectural marvel.

Forging ahead with her attraction to machinery, Driggs painted *Aeroplane* (1928, Figure 8) after her first flight from Cleveland to Detroit. She became so enamored by the

[49] Stavitsky, et al., *Precisionism in America*, 14-15,18, 21.

sensation after sitting with the pilot in the cockpit that afterwards she sketched these innovative machines at the Ford plant after they were fabricated and waiting in hangers for transport.[50] In her painting, Driggs concentrated on the plane instead of the human presence as the windows are shaded and obscure the interior while dark brown lines slant down around the plane like guidewires or rain. The meticulous line quality as they delineation the contours of the corrugated steel body, only changing color to account for the different areas of the craft or reflective light. Even the tri-motors, the front that drives the propeller and the outboard engines on the wings are simplified versions of Ford's engineering.[51] The landing gear underneath the wings and at the end of the fuselage under the tail are also streamlined as they become beige circles for the tires and silver disks in place of the steel rims. While her tribute to the *Aeroplane* and the modern age was focused on the U.S., other artists were methodically examining in detail the function of machinery.

Artists in Europe were also fascinated with new technology like airplanes which had developed into essential machines for travel after World War I. A rendering of the exterior of the plane by Driggs was more common for artists to create than diving into the engineering aspect of the machine which would require a passion for mechanics such as Sonia Delaunay displayed. In 1937 Russian born Parisian Sonia Delaunay designed and executed *Engine* (1937, Figure 9), one of three murals for the Paris International Exhibition of Arts and Technology in Modern Life. Sherry A. Buckberrough has

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[50] Kimmerle*, Elsie Driggs,* 34.

[51] Greg Herrick, *The Amazing Story of America's Oldest Flying Airliner* (Jackson, WY: Yellowstone Aviation Inc., 2004), 2-3. The author rebuilt one of these airplanes and this was his research into the history, mechanics, and statistics of the plane.

discussed the rendition of an airplane's motor, propeller and control panel by analyzing the murals presented by Delaunay. Buckberrough contends that the depictions of these components were "funneled through her imagination" as if they had, "little to do with their actual function."[52] Buckberrough's viewpoint that the designs were from Delaunay's "imagination" is grounded in a background of the arts but her simplistic dismissal demonstrates the absence of an applied mechanical knowledge perspective.

Sonia Delaunay's Odyssey with Machines

Where some artists added machinery fragments to their work, Delaunay demonstrated an intense awareness in how an engine or plane actually functioned through her use of color and line. By pursuing her curiosity about aircrafts she researched how planes functioned before creating the murals.[53] Delaunay was already a successful commercial designer who owned her own business as her husband Robert, also an established artist, continued on developing their color theory Simultanism which was about pure color as affected by movement, light and rhythm.[54] Unlike the commission constraints that hemmed in the artists during WWI, such as the Canadian War Memorials Fund, Delaunay was never employed by any government and was not required to re-creating a direct representation of a factory setting. Instead, Delaunay used color as the medium of how a combustion engine functioned and hydraulic propeller operated.

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[52]Sherry A. Buckberrough, *Sonia Delaunay, A Retrospective* (Buffalo: Albright-Knox Art Gallery, 1980), 86.

[53] Buckberrough, *Sonia Delaunay*, 84-87.

[54] *Sonia Delaunay,* (London: Tate Publishing, 2014), 78.

Machinery has a rhythmic language, which Delaunay captured during an interview when she was asked why she disliked the "mechanical side of things" and yet "collaborated with engineers" while working with illumined signs for Zig Zag papers in 1936.[55] Her response, "we found the life in color in color itself" and how there is a "rhythmic aspect of color."[56] Those who labor on machines view mechanical objects through this lens, which is more than vocabulary of individual pieces, but a cadence that flows through the device.

A close study of Delaunay's *Engine,* reveals that the cylinders and crankshaft are instantly recognizable for those versed in this terminology. After examining the history of the Spitfire airplane, it was Rolls-Royce that built and installed the Merlin V12.[57] Using the Merlin V12 as a template I was able to decipher Delaunay's mural of an engine, noting a cubism influence of showing all of parts of the subject from all sides at once such as the oil pan. The application of a mechanical perspective exemplifies how Delaunay's use of color emphasized the heat exchange capacity of the engine demonstrating her clear understanding of the lubrication system. Oil in an engine has two basic functions, first and foremost to reduce friction between metal parts and secondly, cooling of components inside of the block and head(s). When the lubricant journeys through the maze of passages of these components, the heat exchange properties of the

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[55] Buckberrough, *Sonia Delaunay*, 82-83.

[56] Arthur A. Cohen, *The New Art of Color: The Writings of Robert and Sonia Delaunay* (New York: Viking Press, 1978), 219.

[57] Alfred Price. *Spitfire in Combat,* (Stroud, England: Sutton Publishing Ltd., 2003), 9. The rest of the information about the Merlin engine was from viewing engine diagrams as found on https://www.enginehistory.org and my own knowledge.

cast iron are utilized by the fluid. Delaunay effectively captures this interchange in the painting as her palette reads like a thermodynamic chart.

At the bottom of the painting in the center are two light pink rounded triangular shapes on either side of the light grey rounded trapezoid which would correspond to an engine oil pan, a receptacle for capturing and storing the fluid as it flows back down to the bottom of the engine. The oil is cooled by the channels of coolant circulating through the engine before recycling back up into the passageways. Above each light pink triangle are green half circles with dark pink spheres in the center of each. Next to each sphere is a sliver of light pink. Following the idea of heat exchange, it seems odd that we have green, commonly seen as a cool color compressed between the warm pinks, yet it makes sense as the throws of the crankshaft are thick roughened steel which cause the shaft to rotate but are under no friction. Delauny's choice of color highlights her knowledge of the physics of the rotating assembly. A light pink color would correspond to a cooler temperature more effectively than a red which is often associated with heat. The dark pink sphere would be considered warmer than the oil that has been sitting in the light pink area of the pan.

A vital component of the engine lubrication system is the oil pump which sends the fluid up to the top of the engine. This is not depicted in *Engine.* The only mechanical movement that is documented is of the crankshaft counterweights, which are represented by the green half circles. The counterweights are bathed in oil every time they rotate through the fluid stored in the pan. Their current position in the painting reads as they have completed the second part of their job, throw oil onto the cylinder walls, or the light

pink right triangles. By including this small detail, Delaunay displays the depth of research in understanding the rotating assembly.

A crankshaft spins on main journals or solid precision machined steel cylinders, represented as dark pink circles, which have tapered holes that direct oil onto the metal bearings that the shaft rides on. Bearings are thin pieces of metal that help reduce friction between two metal surfaces. They produce a substantial amount of heat in the engine and require major lubrication and cooling. Delaunay incorporates her sophisticated understanding of this heat transfer process as she rendered a dark pink where the crankshaft journals would spin inside of the crankcase generating heat. The friction from the rotating crankshaft assembly would intensely warm the journals and bearings while the fluid absorbed this heat preventing them from becoming red hot. Otherwise these metal components would weld together and result in catastrophic engine failure.

Engine is colorfully illustrated with enough details that the elements are easily discerned for a trained technician. Within the two light gray masses above the dark pink circles are white squares where their position and shape relative to the crankshaft indicate them as pistons. The combustion chambers which incorporate the heads and block produces the most heat in the engine are cooled by passageways. Inside of the block the pistons skirts glide along the cylinder walls below the heads and only need a splash of oil slung on them from the counterweights to stay cool. One aspect found in this mural that could be overlooked is that the piston to the right in the image, which shows the piston skirt cutout and thin black lines at the top of the white square which stand in for the piston rings. Delauney's addition of this detail brings to mind that engines have one cylinder closer to the front of the block on one bank compared to the other side. This

would tell a technician that for the firing order, this is the number 1 cylinder where all timing is measured from.

The engine heads correspond to the grey mass at the top and within that area, long black lines at a ninety-degree angle emerge from the white squares of the pistons. This a comparable position for an overhead camshaft engine configuration where the rocker arms open and close the combustion chamber valves allowing the air/fuel mixture in and the exhaust gasses out. The valve train is composed of springs, rocker arms, camshafts, and valves but Delauney utilized only the main components to demonstrate her command of the internal combustion process. Engine coolant circulates through the entire system via passageways regulating the temperature for the block and heads including the valve train. Thus the black and grey color still corresponds with Delauney's sense of rhythmic color as the valve train thermal reading would match the heads or block.

Small white thumb-tack shaped objects stick out at odd angles to the grey area resembling spark plugs that are used to ignite the air/fuel mixture.[58] In the middle of both the gray and pink zones, there is a blue section that contains a red circle. The sky blue corresponds to the housing cover that would protect the rotating assembly within the engine and allow for inspections. The cover is removed from any heat, thus the color matches the coolness of sky. The center red circle is where the propeller shaft spins, and anything that rotates on an engine creates heat necessitating a strong red which Delaunay takes into account as this shaft would ultimately connect to the propeller blade assembly as she included the white lined governor control unit connected to a pale yellow circle.

[58] The Merlin V12 engine has two diametrically opposed spark plugs in the head.

On the left of the painting is a coiled black and white figure. Continuing with the idea of heat that Delauney explored because of her knowledge of engines, this S-shaped is similar to a bi-metallic spring that would rely on electricity as a source of heat in order to create a mechanical action, such as the movement of the throttle plates that are responsible for regulating airflow into the combustion chamber. The thick white line emerging from the top of the blue cover that ends could be interpreted as a wire charged with electricity to produce the required heat to expand the coils. The figure is a reminder that often an exploded view of parts is created on schematic drawings letting the viewer know of other parts hidden behind covers.

Another indication that Delaunay was familiar with the function of this engine are the random light gray and white dots on the right of the mural. Since the artist included three spark plugs, which were noted earlier, without more information about the number of cylinders an engineer or technician would be unable to determine the configuration of this engine. Technical drawings include certain symbols that by themselves seem simple but when grouped together, can designate a large amount of data. The six light grey dots number are painted in a circle with a larger white dot in the middle and this symbol occupies the right third of the painting.

This is another area that has been presumptuously dismissed as Delaunay taking "artistic license" with the mural, as if these dots were just randomly placed in the space. Yet this particular arrangement of circles corresponds to the firing order of a 6-cylinder

engine that anyone familiar with reading mechanical service manuals would perceive.[59] The firing order of an engine is vital for any combustion process as it determines when the spark plug will ignite the air/fuel mixture. If the arrangement of when each plug will fire is out of order then the engine will fail to operate and possibly damage internal components. The only part of this figure that is missing is an encompassing circle that contains all of the dots and sometimes there is an arrow showing the direction of rotation. This information was crystal clear to Delaunay through her application of color when tackling the portrayal of an engine that is liberated from a technical schematic or flow chart as she paints with an awareness of how the machinery operates.

Delaunay maintains her vision of color with another mural *Propeller* (1937, Figure 10), the second of three works for the 1937 Paris International Exhibition of Arts and Technology in Modern Life. The artist worked on a colossal scale and her panels for *Propeller* measure twenty-two feet and ten inches by nine feet and seven inches. To provide a sense of the size of these murals, a British Spitfire plane and the Merlin V12 engine were displayed during the exhibition as the plane was lauded as the "fastest in the world" in 1936.[60] The plane measures twenty-nine feet and eleven inches long with a wingspan of thirty-six feet ten inches while the hall that housed the three paintings was eighty feet high.

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[59] The Merlin V12 head has a 4 valve arrangement. The block configuration would have six of the cylinders on one side and six on the other. Delaunay creates half of that firing order in her mural, 1L-3R-4L-5R-2L-1R | 6L-4R-3L-2R-5L-6R since each side is label Right =A and Left =B, with one spark plug coil for each bank.

[60] Price. *Spitfire in Combat,* 35. This was an excellent source for the history of the Spitfire as a versatile machine but little about the mechanics.

When Britain declared war on Germany, the Royal Air Force was able to modify the interior, exterior and engine for various environments and conditions. A 100-Octane fuel mixture of specialized kerosene created by the U.S. coursed through the fuel system which increased the engine's output.[61] This versatility allowed the Canadian, Czech, French, Polish, Russian and American pilots to use the Spitfire as a defense during WWII and beyond until it was retired in 1963.[62] At the time of the plane's creation it was a machine on the cutting edge of technology, where few people were knowledgeable about how it functioned.

Delaunay's monumental renderings travel deeper into the theory of color as movement when she dissects each part of a Constant Speed Propeller, the mechanisms that drive it and numerous other parts of an airplane. Delaunay combines the matte blue typical of a technical drawing for recording the hydraulic pump that tilts the propeller blades in addition to the landing gear and fuel valve. Her perspective for *Propeller* is taken from the cockpit instead of the front of the plane.[63] She provides us with a view of the hydraulic motion of the props as they tilt to control the air speed of the plane. These different colors on the blades correspond to the different gradient angles of wind

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[61] Richard Haitch, "Who Helped Win Battle of Britain," *The New York Times* December 3, 1978, https://www.nytimes.com/1978/12/03/archives/new-jersey-weekly-4-who-helped-win-battle-of-britain.html. The 100-Octane fuel was part of the U.S. effort to increase the Spitfire's output during the WWII which included a specialized kerosene based fuel.

[62] Price. *Spitfire in Combat,* 51, 160-172.

[63] Interview with Bryce Bond, Department Chair Applied Science & Technology, Mesa Community College (MCC)- 8/19/2020. As I work under Mr. Bond, we had many discussions about airplane mechanics as he is also an Automotive Instructor.

deflection. With this palette, Delaney uses hues which are unrelated to temperature which was the main focus utilized in *Engine*.

In the center of the painting *Propeller* are a series of circles which portray the body and cone of the plane along with the details of a hydraulic propeller hub. The forest green circle corresponds with the body of the plane then decreasing circle sizes are a loose representation of the propeller mounting until at the center where the bright colors signify the mechanical movements of the hydraulic pump. The light pink circle is a bearing, which touches upon the idea that it generates heat as reviewed in *Engine*, spins underneath the spring green triangles which are the supports for the grass green elongated triangles of the swash plate rods. Their cylindrical ends are a light gray that terminate with buttons of dark gray whose function is to push on the propeller blades. The inner orange hue is another bearing the blades utilize only to twist from one position to the next. The yellow interior is the hydraulic pump that controls the tilt of the blades with shadows of the propeller ends visible enough within the bright yellow as they attach to the crankshaft, which drives their rotation.

Bands of color on the propeller are recording the wind deflections of the blades pitch which is controlled by the pilot with a lever which Delaunay included next to the left propeller. This leaf green lever pivots at the bottom on a dull orange circle that represents a shaft, similar to the orange inner bearing in the hub. Towards the top of the shaft is a light gray upside-down U-shape that recalls the color of fasteners (nuts and bolts) where a bright red sphere is located. This sphere is color coded the same on aircraft

with tilt propeller blades and corresponds with the tilt lever that is still currently used inside modern cockpits.[64]

Between the red knobbed lever and the propeller, Delaunay places the hydraulic actuator housing where she rendered the cavity in blacks and grays. This schematic scene demonstrates the actions of the piston which tilts the blades. Below the left prop outline in black is the cylinder with marks also in black that resemble the teeth of a comb and correspond to threads. The piston inside of the housing is a black outlined rectangle which appears that it is touching the walls so it would keep pressure on the fluid. Underneath the outlines of the piston are light gray rectangles with a dark gray line that represents the channel that hydraulic fluid would follow to apply pressure on the piston as the crankshaft of the engine feeds fluid into the chamber.

In the upper left of the painting, there are light gray and white circles which are connected by canted gray bands. These circles and bands are delineated by a white rectangle and represent a cutaway view of a double spring. The gray shaft in the middle of the spring is the hydraulic piston. The return spring pushes the piston back into its original location after the fluid has been force the piston down the cylinder by the governor using pressure from the oil pump. Delaunay expertly recorded this theory of hydraulics as she included in the gray mass atop the cavity a technical rendering of the symbol for a spring and valve assembly. The black repeating lines she included on the side of the housing of the actuator look similar to cooling fins for the oil but are cut threads. Along the upper right side of the chamber are cold grey accents which are

[64] Interview with Bryce Bond, Department Applied Science & Technology MCC-8/19/2020. This information is from one of our many conversations about this painting and his knowledge as a licensed pilot.

adjusting gear teeth providing movement for the governor. The amount of specifics for how the hydraulics on the tilt propeller work is too detailed for this mural to be viewed merely as an abstract work of the artist, instead this painting displays Delaunay's command of the theory behind this mechanism.

Delaunay included most of the mechanical portions of the plane as would appear to someone seated in the cockpit. The right side of the painting holds a detailed view of an oil pump which directs the flow of fluid to the constant speed variable pitch propeller.[65] The dark orange circle with smaller yellow-orange circles scattered within that is nearest the propeller pivoting mechanism is the hydraulic piston for the landing gear actuator located next to the pilot. Delaunay's inclusion of this detail of the piston corresponds to how her painting reveals the oiling system used by the airplane. In the lower right corner, a light gray cylindrical relief valve sits atop a pink circle with tiny bright red circles mimicking a tank lid and fasteners. She delicately outlines the assembly in pale cool grays, and only the splash of pale yellow provides a hint of the motion from the valve plate.

To the right of the propellers is a pastel yellow circle with a spiked circle nestled inside where open cavities transfer fluid from one area to another and represents the oil pump that is part of the front of the engine mounted governor. A mint green circular spur gear that transforms their mechanical movement to hydraulic by twisting and turning propellers is also part of the governor. Continuing moving down the painting, Delaunay depicts a pale orange sprocket that would be turned by a chain from the cockpit actuator

[65] Interview with Bryce Bond, Department Chair Applied Science & Technology, MCC. In addition to being a Department Chair, Mr. Bond is also an ASE Master Technician who has built and flown airplanes.

as it raises and lowers the hydraulic shock absorbers of the landing gear as seen by the long shaft laid out horizontally in dark and light grays.

The aspects of these mechanisms that Delaunay rendered within *Propeller* exemplify a comprehension beyond simple observation. Her colors correspond to each component's function. Bearings produce heat as they spin, whereas gears, depending on the size, the friction may generate low heat reflecting the orange and yellow hues that Delaunay had chosen. As with *Engine,* color is used to convey action and provide the characteristics of the hardware, and for a woman, displaying her expertise in such a public space in the 1930's was unheard of. Women who were willing to enter this male space dominated by engineers and mechanics and learn the intricacies of airplanes were rare. Further admittance of women into this mechanical world would come with the onset of WWII as eligible men were conscripted into the armed services.

CHAPTER 4

WORLD WAR II: WOMEN AND PROPAGANDA

With the labor shortage of able-bodied males who were sent into combat during WWI and WWII, a major cultural shift was a necessity as the jobs left behind were in urgent need of skilled workers. Taking advantage of the many new opportunities now available to them, women were hired to operate machinery. Even though they earned higher wages than they had in prior positions, their salaries were disproportionate to those of their male contemporaries for the same work. When women expanded the factory labor force their understanding of technical knowledge was recognized, and their presence challenged the perceptions of male exclusivity as they mastered the complex equipment.

The Ministry of Information in Britain and the U.S. Office of War Information continued commissioning artists during WWII as they had for WWI. They sent artists to locations across the world amassing a rich trove of materials in the Imperial War Museum and the Library of Congress. These archives provide invaluable documentation on how these women became proficient with the instruments they handled and on the artists who recorded them along with their assignments during the wars. In addition to both governments, private U.S. corporations also employed women artists to record the war effort and these entities uplifted the role of the female non-combatants.

As Europe grappled with hostilities between nations, artists were on hand to record the effects of war. M. Thérèse Bonney was in Finland in 1939 when Russia invaded, she captured the event with her camera, turning her into a war correspondent. Her courage was recognized by the Finish government which awarded her the Order of

the White Rose, their highest honor, as she sought out images of soldiers in the trenches, the Red Cross tending the wounded, and fleeing distressed inhabitants.[66] Bonney had intended on covering the Olympics, since she found the photographers of her time unable to provide a dramatic flair to their images, these photos were a far cry from her original objective.[67]

Born in New York, Bonney was raised in California, graduating from the University of California, Berkeley and then a master of arts in romance languages from Harvard before becoming part of an international exchange student program between Columbia University in New York and the College of Sorbonne of Paris.[68] Bonney became the fourth woman to earn a PhD in 1921 from Sorbonne with her dissertation on "Ethical Ideas in the Theater of Alexandre Dumas."[69] Employing her fluency in French and Spanish, Bonney established a business, Bonney Service. This was the first press agency between the U.S. and European that promoted artists through advertising and

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[66] Carol McCusker, *Breaking the Frame: Pioneering Women in Photojournalism* (San Diego: Museum of Photographic Arts, 2006), 20.

[67] Paula E. Calvin and Deborah A. Deacon, *American Women Artists in Wartime*, *1776 - 2010* (Jefferson, NC: McFarland & Company Inc., 2011), 98-99.

[68] Naomi Rosenblum, *A History of Women Photographers* (New York: Abbeville Press, 1994), 295. Both Rosenblum and McCusker were unable to name which university Bonney graduated with her masters where Kolosek in *The Invention of Chic,* names Berkeley.

[69] Lisa Schlansker Kolosek, *The Invention of Chic: Thérèse Bonney and Paris Moderne* (New York: Thames & Hudson, 2000), 25-27. College of Sorbonne is now the University of Paris. Nan Robertson, "In a Life of Firsts, She Has Few Regrets." *New York Times*, July 25, 1976. This interview listed Bonney as attending Harvard and Columbia for a masters degree before going to Sorbonne.

photography as they sold content to newspapers on both continents.[70] By the 1930's Bonney was immersed in the arts, curating shows in New York and Paris as she moved in artistic circles and counted among her friends Sonia Delaunay, Elsa Schiaparelli, Janet Flanner, Raoul Dufy, Ambroise Vollard and Georges Rouault.[71] When Germany invaded Poland, an event that started WWII in 1939, Bonney left the art world to concentrate on documenting the war.

Bonney was fluent in multiple languages and well connected, which made her a prime figure for recruitment by the Office of Strategic Services.[72] Her tenacity and fame provided her access to areas that would have been barred to others, such as entering concentration camps, passing sensitive information to the British and photographing the looted art recovered by the Allies. For Bonney, photographing the war was personal, her connection to the U.S. government incidental as she recorded *Women Airmen Learning Engine Maintenance From a Member of the RAF* (1939-1943, Figure 11).

Bonney photographed five women with hair neatly tucked under caps or hats who are gathered around the head of an engine with one man evaluating their hands as he appears to be looking down while they learn an important maintenance task, valve adjustment. Similar to the ambulance drivers Edis had photographed during WWI, these

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[70] McCusker, *Breaking the Frame*, 19. According to Rosenblum, Bonney's masters was in romance languages and Kolosek*,* Bonney's bachelors concentrated on French and Spanish. McCusker does point out that Bonney's dissertation was about French theater and titled in French, which is assumed was also written in French.

[71] McCusker, *Breaking the Frame,* 19.

[72] McCusker, *Breaking the Frame*, 22. Office of Strategic Services (OSS) was the precursor to the CIA.

women are developing the same skill, checking clearance between the rocker arms and valve stem tips with feeler gauges.

Adjustment of the valve train requires a mechanic to understand the reason behind such fine tuning, but more than that, what the consequences would be if done incorrectly. If the clearance is too tight this could cause bent valves and damage the head. If the clearance is loose, then the valve will stay closed causing the engine to run poorly.[73] The female figure in the foreground with her back to the viewer holds in her left hand a steel feeler gauge and in her right a wrench. The adjustment she performs requires a slight drag on the gauge which encompasses thickness variations from a thinner than paper .0015 of an inch to a tin can thickness of .035 of an inch. These are read by how they feel when dragged between the valve tip and rocker arm and it is through repetition with experienced personnel that trains the mechanics hands to 'read' the correct value.

All the women's hands are in the head adjusting an overhead camshaft (OHC) valve train and mounted at the end of the cam is an axial beveled gear mated to another beveled gear on a shaft plunging down into the block. The gear driven shafts are in line with the gear reduction principles as the cams are turned though a series of chamfered and straight gears by the crankshaft, controlling the opening and closing of the valves. The three women on the other bank of the engine are performing the same task, checking the valves for the proper drag. Determining the cylinder configuration is difficult with five women practicing on the valve train as they block the view of the engine. Yet as

[73] Firing order for the Merlin is 1L-3R-4L-5R-2L-1R | 6L-4R-3L-2R-5L-6R with both No.1 at the rear or opposite the propeller. Companion cylinders are 1 and 6, since they are in the same position in the block at the same time.

these are women training for aeronautics, I am led to believe that this is a V12 Merlin they manipulating due to the size and valve train arrangement.

Even with the extensive length of the head of the engine, five people adjusting valve timing at once appears improbable. Examining the Merlin's firing order, the crankshaft would have four pistons at Top Dead Center (TDC) of their rotation. Only on the compression stroke in the 4-stroke process for a combustion engine, meaning all the valves are closed, are the valves ready for adjustment. This is an important step as the head for the Merlin has four valves per cylinder, two for the intake and two for the exhaust, with the four pistons at TDC, that means only two cylinders would have all four valve closed. This is dissimilar to the common V8 engine that would only have two cylinder at a time available to have the clearance checked. Judging by the drive gear of the camshaft in relation to the rocker arms, the women with a feeler gage in her hand with her back toward the viewer is adjusting cylinder number 2 on the right bank or side of the engine. When following the firing order, then the companion cylinder or the other piston at TDC, would be number 5 also on the right. Then at the same time, number 5 on the left bank is at TDC with valves sealed and number 2- Left would have the exhaust valves open.

With this information, only two women would be able to adjust valves, yet there are five women. The three in the back are watching one woman using a flat-blade screwdriver to fine-tune the rocker where in the front one woman is looking down, her hands out of view. While Bonney has depicted knowledgeable women in the midst of training, the fact that there are so many women at one engine gives the feeling of being staged in the service of a publicity stunt. Often hands-on technical training is completed

in groups, relying on the information of everyone involved or offers of assistance during the task while learning from the component and each other, essential when toiling in repair shops. Bonney uses her lens to capture more than the women clustering around an engine, she emphasizes their skillset and camaraderie as well.

Continuing her mission of recording female operators Bonney photographed *Women Factory Workers Working on Machines in a Munitions Factory* (1939-1943, Figure 12). A youthful female operator is in the process of drilling a section of metal using a radial arm drill press. Her loose clothes carefully tied way from spinning parts with her hair fashionably coiffed as clean hands hold the press and a smile appears on her face. This stands in stark contrast to dour faces in *Members Of Queen Mary's Army Auxiliary Corps* by Edis and the crowded conditions observed in May's *Women Making Shells* during WWI. Grime on their clothes with hair hidden under hats are how the *Ambulance drivers of the Voluntary Aid Detachment* women are recorded by Edis out in the field utilizing their skills to help win the war, which is opposite of Bonney's image.

The drill press and operator are the only subjects in the frame, other workers are out of sight and the background of the shop is blurred. Absent is the millwork in the rafters with a sea of tentacle like bands wrapping around the machines as observed in the factories of WWI. Instead electricity now dominates the industrial areas as the drill is run by an electric motor mounted in the head or at the top of the press. The hazy crowded conditions of the shop floor had developed into a more polished and organized space as technology advanced, along with operator safety. Exposed belts are hidden behind rounded metal panels which would be at eye level with the female machinist in the photo. The large adjustment wheel her hand grasps moves the head of the machine towards or

away from the operator. While the handle in the woman's right grips lowers the rotating cylindrical chuck down, which encases the drill bit, on to the metal. Tubing has been routed to the vise on the table of the press that the metal is clamped in a for cooling while a pan collects the fluid and shavings.

Operators for a radial arm press would require more training than those who use a standard drill press which only requires for the user to adjust the table. The radial arm requires additional preparations before use, the head of the drill is coordinated by horizonal movement then by vertical movement and finally a rotational movement. Once all three axis were modified then the machine is locked in place before the motor is turned on and the chuck guided down to the table to begin the process. With machining, precision is key, as manufacturing would have the user prepare the press for a batch of parts. If the calculations are off, then the whole batch is ruined, wasting time and critical resources.

The female machinist that Bonney has photographed displays her expertise with the type of machine she operates. In Bonney's *Women Airmen Learning Engine Maintenance,* the emphasis is less on the face and more on their training as the engine is the focal point of the photo. In *Women Factory Workers Working on Machines in a Munitions Factory,* Bonney is showcasing more than the skill of the woman operator, she highlights the satisfaction the subject displays. Women could still be feminine while working what were considered masculine jobs that required learning technology long deemed male-orientated as Bonney's composition is as much about advertisement for the factories as it is for skilled women.

Working artists like Ethel Léontine Gabain wanted to immortalize those women who were encouraged to fill the vacancies left behind as they learned how to fabricate parts for various machines through a series of lithographs documenting their occupations. Born in France in 1883, Gabain was in poor health by the time Britain entered WWII, yet she was determined to record the contributions that women made to the war effort.[74] She volunteered her services to the Ministry of Information shortly after the loss of her youngest son, Christopher in 1940.[75] Gabain's family supported her talents since the beginning as she enrolled in both the Slade School of Fine Art and the Central School of Arts & Crafts of London in 1906 and started exhibiting at the Walker Art Gallery in Liverpool two years later.[76] It was during her time at Central School of Arts & Crafts where she discovered lithography which became her focus for the rest of her artistic career.

The War Artist Advisory Committee (WAAC) of Britain declined to include industry workers as appropriate subjects for documentation. Gabain disagreed with their stance and sought women who were employed at factories to chronicle their perseverance and due to her tenacity, the WAAC accepted her lithographs.[77] With a general disregard

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[74] Susan Thomson, *The Life and Works of Ethel Gabain* (Warrington, UK: Manchester Art Press Ltd., 2008), 7-8, 52.

[75] Thomson, *The Life and Works of Ethel Gabain, 52.*

[76] Iain Pears, *The Lithographs of Ethel Gabain 1883-1950* (London: The Fine Art Society Ltd., 2003), 5. Harold J. L. Wright, *The Lithographs of John Copley and Ethel Gabain* (Chicago: Albert Roullier Art Galleries, 1924), 68. Thomson, *The Life and Works of Ethel Gabain,*10. All present Gabain's education differently, adding and leaving out institutions.

[77] Thomson, *The Life and Works of Ethel Gabain*, 66.

for official paperwork, Gabain spent hours interacting with women onsite as she preferred to sketch directly on to the lithograph stone and generated prints such as *Work on a Weir Pump Women's Work in the War* (1941, Figure 13).[78] Gabain had worked with a gallerist Harold Wright since 1909 who dealt with the complexities of administration, leaving her unprepared for the amount of documentation that the government would require.[79] Undeterred Gabin would travel to various places, minus the proper permits or permission from the Ministry of Information, however she was so highly regarded that the WAAC often came to her aid by providing the accommodations. Noted by her eldest son Peter, "No matter how hard she worked and how ill she became, my mother would not give up."[80]

Gabain's print captures the grittiness of the shop around managing a capstan lathe and the reflected light from smooth surfaces as she renders the machinery in detail. Her choice of a hazy theme for her print depicts the granular feel to the air as these industrial lathes cut off minuscule amounts of metal, the waste is often in the form of flakes as the material is shaved more than cut. The constant milling of pieces from several lathes all running at once sends these metal particles into the air which lands on workers, equipment and floors. Gabain reproduces this atmosphere in *Work on a Weir Pump Women's Work in the War* as this dust obscures the fine details of the lathe and the part being generated. Other than the lamps scattered through the factory, the machinist's face and arms are the next brightest points, providing the focus of the print.

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[78] Pears, *The Lithographs of Ethel Gabain*, 8-9.

[79] Pears, *The Lithographs of Ethel Gabain*, 9.

[80] Thomson, *The Life and Works of Ethel Gabain*, 52.

With her sleeves rolled up and hair covered for safety as the twirling drum, located below her grip on the control lever, could easily grab loose articles and pull the worker into the lathe with fatal results. With two figures in the space, using light and detail, Gabain pulls the eye back to the women on the left with the easily discernible brightly lit face and her unblemished arms and hands. The female operator has tidy hair, much like Bonney's radial drill press operator, while her clothes appear stain free. The worker's near smile echoes those found in the ladies training on the Merlin engine. Although Gabain is sensitive of how the women are portrayed in her art, she was determined to include their skill set.

The grim interior which with the female operator functions as she adjusts the controls of the lathe obscures most of the environment but Gabain has rendered enough details to determine that this is a Capstan Lathe that is different than the more common Turret Lathe.[81] Near the forearm of the machinist the tall T-shaped handle is mounted in the hexagonal turret tool head that identifies this as a Capstan as does the distinct handles of the turnstile or capstan wheel at the lower left on the long lathe bed.

Without standing behind the female worker, the viewer is unable to identify if this lathe was made by Ward and one of their 2A models, which was the most common one used in manufacturing before WWII. Particulars such as the handles and lack of tail stock on the bed of the lathe helps firmly categorize the type of lathe as a Capstan. Unlike the Engine Lathe or Center Lathe this instrument was developed specifically for mass production allowing the machinist to fabricate a large batch of small parts with minimal

[81] Interview with J. Derek White, Manufacturing Quality Control Inspector and AWS Certification of Welding Inspectors for Aerospace Applications.

oversight.[82] The Capstan can machine small pieces then change tools quickly as they are fitted in the hexagonal tool head which could be rotated. This is one of two lathes that operators could quickly learn with modest training.

From the angle of this lithograph, one of two tool posts block the view of spinning drum of the lathe and help frame the operators arm, accenting the T-handle that allows the machinist to change tooling quickly. The semi-circle below the woman's hand highlights the chuck that clamps the billet or metal being cut inside of the chuck's jaws. Following the line of the top of the T-handle to the right is another long bar with several other lines moving off. They would correspond to oil tubes that lubricate the cutting bit at the end of the boring bar and cool the metal as it washes away debris. As the oil hits the turning piece, the worker's clothing would become splattered and oil soaked, and so coveralls are the usual uniform. Under the drum that houses the chuck is the cross slide that is perpendicular to the bed of the lathe where the tool posts are mounted. It is in this area that the operator machines the parts for a Weir pump.

A Weir pump uses a dual piston mounted on an single rod that was motivated by steam which entered and exited from either side of the piston within two separate cylinders. Ships used steam to glide across the water, those engines needed a way to pump water inside in order to convert the water to steam. The friction of the piston moving within each cylinder under pressure were bound to wear out due to the nature of the movement. Since these pumps had a number of valves for venting the steam, allowing for the action of the piston to move from one side of the cylinder to the other purely by

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[82] Helmi A. Youssef, and Hassan El-Hofy, *Machining Technology: Machine Tools and Operations* (Baton Rouge: Taylor & Francis Group, 2008), 217.

steam pressure which could reach up to 200 pounds per square inch.[83] The Weir brothers developed a double-acting feed pump in 1871 that grew from a single to a double feed pump that would use four cylinders, two rods and four pistons and numerous valves.[84] These small and easy to manufacture parts would require few machining steps to create and were ideal for new operators using the capstan lathe.

Reflections off the glossy surfaces of the hexagonal turret between the tool supports showcase the different tools used as they jut out from each side of the hexagon under the machinist's arm. Left of the turret is a wheel half hidden in shadow near the operator's hip, this is the feed wheel for the slide. The index bolts at the end of the ram in the lower left corner are rendered by Gabain which stop the slide from moving the work and destroying the precision of the cut. The workspace is clear of debris that could affect the ram from moving smoothly toward the drum mounted on the headstock spindle. Next to the drum to the right are square bars neatly aligned, as in any profession that requires measurements, these are templates or gauge blocks that assist the machinist in producing work at a precise length.[85]

Gabain's inclusion of specific characteristics of the lathe allowed for identification of the type used by women in the industry and how the workspace was set up, metal guards between the other lathes and space between operators for the safety.

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[83] Edward C. R Marks, *Notes on the Construction and Working of Pumps* (London: The Technical Publishing Company Limited, 1902), 46.

[84] "About Us - A History Of Innovative Engineering" The Weir Group PLC, accessed 2020, https://www.global.weir/about-us/a-history-of-innovative-engineering.

[85] From my interview with J. Derek White, Manufacturing Quality Control Inspector and Welding Inspector for Aerospace Applications.

These elements in the print helped capture the environment realistically, including the pose of the woman and her clothes to the lay-out of the equipment speak of a shop actually designed for working women instead of a space solely for propaganda.

Gabain's prior body of work was known for melancholy women devoid of background except to ground the figure in the space.[86] She was a fierce advocate for industrial women for she believed that they enjoyed their new roles, these prints differed significantly from her older works. Since these female laborers were not sacrificing their identities, this influenced her perception that "they are all ladies, not women"[87] This idea is effortlessly rendered in *A Tapping Machine Operator* (1941, Figure 14) where a female machinist in a crisp white shirt with clean limbs and hair neatly arranged interacts with her machine. Compared to the female lathe operator in *Work on a Weir Pump Women's Work in the War*, this print supports Gabian's view as the Herbert No.2 Flash Tapper Tapping Machine is the only component near the figure with a window in the background for perspective.[88] The worker is not smiling nor is she frowning as she exchanges the long metal cylinders or billets in the vise.

Runing the tapper machine is comparable to a drill press but more exacting since instead of making a hole by drilling, threads are cut out of the interior of a billet using a specialized thread cutter, or tap. Located behind the operators hands and chuck are baskets of new billets ready for tapping. The process is run slower and the tap is required

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[86] Thomson, *The Life and Works of Ethel Gabain*,14-17, 64-66.

[87] Pears, *The Lithographs of Ethel Gabain,* 9.

[88] Searching for "Tapping Machine" yields many images on the internet, which I then narrowed down by the configuration of the machine. Surprisingly, I was able to match most of the machines thanks to intimate details provided by the artists.

to be square or at a 90 degree angle with the stock. If the hole is offset, then the fastener would sit at an angle unable to successfully clamp the objects together at the recommended torque value which could cause the parts to fail. Gabain included a container in the lower left with examples of the cylindrical billets and at the end of each a recessed hole where the tap entered creating the threads.

As in all machining processes, the tapper has a length of hose for oil running alongside with the tip at the chuck to lubricate and cool. Distinctive to this machine is that the table has been purposefully built as a tray with groves for the vise to mount and catch the fluid. A successful operator would understand how critical the rotating speed, the movement of the tap down and up and most importantly when the chuck should be stopped. Any variation and the threads would sustain damage and ruin the part.

At first glance, a pristine lady seated at a machine appears as performing a simple operation. This is a deceptive assumption as oil would fling onto the operator from the spinning chuck. Also the amount of essential training, including a particular sort of patience and an inherent meticulousness is required to perform the task. Gabain presents both the feminine qualities by the worker's appearance while still showcasing one of the many aspects of specialized knowledge required for machining.

One of the themes the U.S. Office of War Information requested of artists was illustrating women in essential jobs who had undertaken these positions as a demonstration of their support for the war effort. An assignment in California allowed photographer Ann Rosener to journey out to the docks in Richmond and photograph *California Shipyard Workers* (1943, Figure 15). She was one of eight women who completed assignments for the Office of War Information and as a photojournalist her

subjects spanned women working outside the home, services for health and nutrition, home economics, and finally, those who ignored social restrictions so they could add their labor to the workforce.[89] She included women and men of color, and those who had physical handicaps both female or male contributing to the manufacturing of items needed for the front. Of all the women photographers who had documented the activities surrounding WWII, Rosener made approximately 800 images but as a modest woman she declined interviews and preferred her privacy. Consequently, her photos were buried in history.[90]

A San Francisco, California native, Rosener graduated in 1939 from Smith College, in Northampton, Massachusetts, with a focus on poetry and literature before moving back to the west coast. She was provided a cosmopolitan upbring as her father was a mining engineer and her mother the daughter of a successful business owner. With servants from Europe, Japan and the U.S. in their household, Rosener worked on liberating her thinking away from her lavish upbringing.[91] When the U.S. entered the war in 1941, she was hired as a photographer for the Office of War Information who sent her

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[89] Beverly W. Brannan, *Ann Rosener (1914-2012). Introduction & Biographical Essay* (Library of Congress, Washington, D.C.) Andrea Fisher, *Let Us Now Praise Famous Women: Women Photographers for the U.S. Government 1935 to 1944* (New York: Pandora Press, 1987), 9. Fisher found for her book that there was little information about the life of Ann Rosener. The introduction by Brannan agrees with Fisher's assessment as the reason that she created the biographical essay for Rosener.

[90] Brannan, *Ann Rosener* (Library of Congress, Washington, D.C.).

[91] "Ann Rosener: Obituary," *San Francisco Chronicle,* June 5-6, 2012. Brannan, *Ann Rosener* (Library of Congress, Washington, D.C.). Brannan cites part of the obituary in her essay.

on thirty-one commissions in locations around California, Illinois, Iowa, Maryland, Michigan, Wisconsin, and Washington, DC.[92]

In *California Shipyard Workers*, a female welder with "Ada" inscribed on the side of her welding helmet sits at the intersection of four steel plates. Her hands encased in heavy welding gloves as she holds a wand with a rod clamped in its jaws while dressed in a thick specialized leather jacket. Even without a machine in sight, the long cable snakes away to the far back left corner towards the welding machine or welder. This device is a type of electric transformer that uses wound wires for electromagnetic induction and unlike other machinery, this system contains no moving parts. The size and type of welder determines the amount of amperage and volts it is capable of producing for the duty cycle, all of which are adjustable.

Rosener focused her lens on a single figure and strips the background of other clues of the work the woman is preforming. The blurred figure in the back is nondescript and blends in with the steel plates other than the one work boot. Capturing which trade the participants are involved in relies on the caption. Rosener seems fixated on portraying the welder as an example of those women who were proud to support the war effort on the home front with their machinery work. The small items in the photograph are evidence of the welder's accomplishment, the box of electrode rods, a welding hammer with a distinct coiled wire handle, and a steel bristle brush for the cleaning of the area

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[92] *Biographical Note, Ann Rosener papers (M1946)* (Dept. of Special Collections and University Archives, Stanford: Stanford University Libraries, 2014). Rosener worked at Stanford from 1964 -1988 where her collection of photographs, posters, correspondence, drafts, exhibition catalogs and business records from her private press are stored.

prior to and after welding. The seam with broken slag behind her circled with white chalk indicates the area she is repairing.

Stick or arc welding is one of the most challenging types of welding to learn. The rod conducts electricity through its metal core that melts it's coating which creates a pool around the area. Compared to the three other welding types, tungsten inert gas (TIG), metal inert gas (MIG) and oxyacetylene or gas welding, stick requires more skill as an arc is created between the electrode and the surface. Arc welding produces slag build up that requires removal, a hammer breaks it up and the wire brush cleans the area. Advantages for this process is that the area can have rust, be outdoors even in windy areas and is extremely portable, perfect for welding ship plates.

The photograph displays a cheerful young women with her helmet up exposing her bright face happily stopping to pose in the midst of her job. The long heavy leather coat obscuring the definitions of her body while the thick welding gloves hiding her hands are the only evidence that her knowledge is a composite of training more robust than others.

As part of her photography series of women working in production, Rosener presents a female drill press operator in *Women in Industry. Aircraft Motor Workers* (1942, Figure 16). The lack of other machines in this manufacturing warehouse provides a false sense of space around the lone worker. Rosener focuses solely on the woman and the drill press she is attentively running rather than crowd the photo with other equipment. The operator's hair is fashionably styled away from her face and in a hairnet prohibiting any locks from becoming entangled in the machinery. Without a supporting

cast of male coworkers, supervisor or other operators, Rosener signifies that the woman is well adept at completing her task.

An upright electric motor with long cord hanging down in the lower right of the photograph is bolted to the shaft of the press. A belt mounted on the motor pully transfers power to the drill press wheels stacked on top of each other behind the guard protecting the worker. Depending on the operator's requirements the pulleys allow adjustment to the chuck shaft as the motor can slide up or down and align with the different wheels. The various sizes are capable of delivering either less speed by using a larger disc or more speed with a smaller diameter. This follows gear ratio principles of if a large pully drives a pully that is smaller it will add speed with less torque to the spinning chuck below.

In fresh coveralls and her crisp white shirt with sleeves rolled up and out of the way of rotating assemblies this woman is almost a paradigm of safety. Lacking eye protection and wearing what appears to be sandals on her feet would constitute a safety hazard for workers in today's industrial environment. Rosner has emphasized the spotlessness of the area including the table of the press where a bracket clamps down a L-shaped block that holds the item steady for the machinist to drill. Minus the clamping force of a vise, the operator holds in her left hand the metal part while her right grasps the lever that controls the lowering of the spinning drill bit.

Sharp metal flakes of metal that are the byproduct of drilling are often flung away from the bit as seen on the table. The lubrication oil usually required during machining as it extends the life of the bits by cooling the metal and keeping the area free of debris is noticeably absent. A small brush hooked around the table adjustment lever is a type of pipe brush only used for cleaning the filings out of the holes after drilling. The

machinist's concentration on the component brings attention to her skill. She is able to quickly drill the part as the missing vise would only slow her down, and the bracket on the table is a guide that depends on the operator to understand the limitations.

Rosener has prioritized the female figure in order to emphasizes her commitment to exhibit the industrial complex's contributions in the time of war, even if the model lacks a smile. The machinery, at first glance, maximizes its complexity with exposed internals as it transmits an air of authority to the operator through its intricacy but it is the worker's hands that are a testament to woman's skill. Rosener has struck a balance between a machinist as a lady and a operator with a specialized skill independent of gender.

The U.S. Office of War Information hired painters, mostly male, as WWII united the country while commercial businesses produced advertisements in support of the war. *Life* magazine editor Daniel Longwell was contacted by Edna Reindel about producing a series of painting for their June 5, 1944 issue related to the home front.[93] Reindel was an illustrator and painter working in New York after she graduated from Pratt Institute in 1923.[94] During the 1930's she worked under the Works Progress Administration creating public works as a painter and sculptor.[95] She moved to California the year before WWII

[93] Speck, *Beyond the Battlefield*, 141-142.

[94] Calvin and Deacon, *American Women Artists in Wartime*, 111.

[95] Calvin and Deacon, *American Women Artists in Wartime,* 111.

began in 1939 and exhibited her work in a solo show at the Los Angeles County Museum in 1940.[96]

Reindel's paintings featured realistic compositions, something that made her an ideal candidate for visually documenting the contributions that women made to the war effort.[97] *Life* magazine was already familiar with her work when they had covered American Magic Realism in the 1930's before she approached them about creating a series that illustrated the jobs that women were preforming. *Life* agreed with Reindel's proposal of the women employed in jobs originally held by men, where they now earned better wages, and offered her the commission. The artist approached her subjects first by engaging in conversation about their positions then observing them operating tools that created the machines employed in war.

A photograph of Reindel that accompanied the *Life* article displayed how she had arranged herself next to her subject, close to the shower of sparks, open toed shoes and a short skirt. The image of the artist is in strong contrast to her model, Rosemary Wylde a university student, who is in appropriately attired for the surroundings in a long heavy type material pants and a long sleeved shirt.[98] On Reindel's easel is the sketch for *Calship Burner* (1944, Figure 17), a women dressed in thick one piece overalls, hair bound in a tight covering with heavy leather gloves armored against the metal fragments.

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[96] Speck, *Beyond the Battlefield*, 297. The Los Angeles County Museum was part of the Los Angeles Museum of History, Science and Art, founded in 1910 and separated into the Los Angeles County Museum of Art in 1961.

[97] Robert Henkes, *American Women Painters of the 1930s and 1940s: The Lives and Work of Ten Artists* (Jefferson, NC: McFarland, 1991), 195.

[98] Published in *Life* 16, no.23, June 5, 1944, page 73. Only a couple of the models names are included in the article under the picture headings.

This contrasts with the skirts seen in the works from WWI of Edis and May's factory workers or Gabin's and Bonney's machinists portrayed in clothing with rolled sleeves, hair neatly style within their bindings, functional along with safety in mind. Welders cover their bare arms with long sleeves, keeping them free from burns from stray sparks with hair likewise protected. Pants protect the wearer's legs against the spray of hot metal and the only detail missing are the boots seen on Rosener's workers. Leather gloves allow the welder the ability to adjust the heated metal or the magnets used for holding stock in place as a guide besides withstanding the high heat generated by the torch without injury.

A green face shield has been lifted away from Wylde's face, defeating the intended purpose of the tinted lens protecting the retinas from the glare of an oxyacetylene torch and from stray metal granules. Both hoses that feed the torch are red which is concerning as a cutting torch uses, by definition, highly combustible acetylene gas and oxygen. For safety, the fuel line, in this case acetylene, is color coded red with the oxygen hose green in the U.S. With both hoses depicted as red, this becomes problematic as this would imply that only acetylene gas is in use by the wielder, resulting in an impossible and highly dangerous situation. Contrary to Kathrine Speck in *Women, Art and Wartime Industries: A Feminist Inter/Modern Analysis*, the oxyacetylene torch has more in common with an ordinary propane gas grill than an electric transformer that is a welding machine.[99]

[99] Catherine Speck, "Women, Art and Wartime Industries: A Feminist Inter/Modern Analysis," *Australian Feminist Studies* 34, no. 101 (October 2019): 7.

Unlike machinists, welders use fewer tools and clutter is counterproductive as material in the area could create a fire hazard. Reindel establishes her understanding of how debris interferes with this process as she visited the yards and factories to capture her subjects as in *Calship Welder* (1944, Figure 18) where a female welder is arc welding two thick metal beams.[100] The gender of the operator is ambiguous due to the amount of safety clothing and gear which makes identification impossible except for the pink headscarf. The heavy leather welding coat and long bulky gloves ensure that the wearer is safe from the slag or molten metal expelled by the rod. A bright spark of hot metal is observed falling near her knee and near the lead cable which emphasizes the lack of refuse on the floor surrounding the welding area and the density of her leather pants. The helmet with square dark lens safeguards the welder's eyes from flash burn while obscuring any identifying features. Unlike Rosener who included Ada's name on the helmet, Reindel is invested in her showcasing skill instead of her smile.

A male colleague dressed similarly with dark googles holds his hand up over the retina searing light as his eye coverings are insufficient to shield him from the radiation, thus unable to perceive the weld created until after she has stopped. When working, the intensity of the flash is such that it is difficult to discern the surroundings outside of the small pocket while the loud sizzle and cracking noise is damped by the helmet that covers the ears. When Henkes mentions that there is "an eerie dialog between the two humans" this seems out of place as until both parties remove helmet and goggles neither are able to

[100] Porter, "Paper Bullets: The Office of War Information and American World War II Print Propaganda," 295. Researched the Postcard from the exhibit at the MacBeth Gallery in 1944, B16373418.PDF in Metropolitan Museum of Art's library website: www.libmma.org/digital_files/macbeth/

communicate with each other by words or gestures since their vision is severely restricted.[101]

Reindel includes details such as the workers hands as they steadily grasp the electrode holder that is clamped around a rod. The female operator is fabricating the lattice for the assembly line using stick welding which requires meticulous control in order to form a good arc.[102] The arc welding electrode or "rod" is available in different types depending on which current, AC (Alternating Current) or DC (Direct Current) and if it is negative or positive and the position of the weld, all this is dependent upon the application. The transformer of the welder is off to the side unseen along with the work or ground cable with only the red electrode or lead cable visible. Reindel's exclusion of the arc welder simplifies the process of welding down to the bright flash of the arc which the painting focuses on as this is where the expertise of the craft is seen. The flash created during the welding process is not a flame as incorrectly labeled by Henkes, for arc welding is different than gas welding which does utilize a flame and wearing goggles is sufficient protection compared to using a transformer that produces eye damaging bursts of electric light.[103]

Reindel has included in the frame of *Calship Welder* the tools that a welder requires, a steel bristle brush for slag and additional welding rods but the chipping hammer is missing that also would be carried in a welder's pail. At the base of the

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[101] Henkes, *American Women Painters of the 1930s and 1940s,* 199. Henkes changes the name of *Calship Welder* and calls it *In Plate Shop* in reference to the *Life* magazine article.

[102] Henkes, *American Women Painters,* 199.

[103] Henkes, *American Women Painters,* 199.

container, a small rectangle pan accepts the molten discarded rod ends. Welding is a skill that takes weeks to learn, months of practice to become proficient and years to master.

Reindel engaged her subjects on a personal basis, she asked the reasons they decided to work at a ship building yard and learned personal anecdotes. For an artist that decided to advance the women who answered the call to fill factory jobs independent of government influence, her paintings are less propaganda induced as they center around the actual skill of each worker and concentrate less on physical appearance.

In the 1930's the U.S. government provided funding to programs like the Farm Security Administration (FSA) that employed photographers such as Ann Rosener, Marion Post Wolcott, Esther Bubley, Dorothea Lange, and Barbara Wright.[104] Yet, no matter how proficient a woman became, men viewed any new technology in the hands of women too complex for them to understand. Wolcott who went to New York University and taught at the University of Vienna before being added as a staff photographer for the Philadelphia Evening Bulletin, relayed that while out on assignment for the FSA she encountered,

> "Whether or not it's very obvious that one is working, there are always a million blokes who want you to either teach them photography, explain the mechanics of your and their cameras, or else they're sure they have some valuable information concerning the country."[105]

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[104] Katherine H. Adams, and Michael L. Keene, *Women, Art and the New Deal* (Jefferson, NC: McFarland & Company, Inc., 2015), 19.

[105] Adams, and Keene, *Women, Art and the New Deal*, 20-21.

These women were on assignments nearly all the way up to when the U.S. entered World War II before the Office of War Information started bringing new artists on their payroll. Female photographers were still valued as Wright was one of the eight who entered factories and recorded those women who had trained to run the machinery.

Background information on Wright is scarce. When I contacted a staff member in the Prints & Photographs Division in the Library of Congress and inquired about Wright, who has over 2500 photographs in their collection, they were unable to provide any biographical material.[106] Further research netted instances of her touring the country with Annemarie Schwarzenbach, a Swiss photojournalist who arrived in the U.S. under the New Deal.[107] Schwarzenbach was described as the embodiment of "modern lesbian chic" which emerged during the censorship of the first lesbian novel in the English language, *The Well of Loneliness* by Radclyffe Hall. In an article about Schwarzenbach discussing her background and work, it was noted that there was a "highly significant" effect that Wright had on Schwarzenbach's career.[108]

Who was Wright? Was she romantically involved in with Schwarzenbach? Has she been erased from history for her possible sexual orientation and this is the reason documentation of her has been lost? The only correspondence I was able to source was a letter dated July 14, 1941 from Wright to the Regional Director Orren H. Lull for the National Youth Administration. The Library of Congress has on file photos taken by

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[106] Personal correspondence by email with the Library of Congress on March 1, 2021.

[107] Leena Eilittä, " ''This Can Only Come to a Bad End': Annemarie Schwarzenbach's Critique of National Socialism in Her Reports and Photography from Europe," *Women in German Yearbook* 26, no. 1 (2010): 97-116.

[108] Dieterle, Regina. "Annemarie Schwarzenbach: Swiss Photo-journalist of the 1930s." *History of Photography* 22, no. 3 (January 2015): 224.

Wright for the Office of War Information, but they are unavailable online. Without deeper research on Wright, her achievements will continue as a footnotes.

Wright shot this photo in 1941 and it is captioned, *Miscellaneous lot of photographs. National Youth Administration (NYA), Works Progress Administration (WPA) and Civilian Conservation Corps (CCC)* (1941, Figure 19) where a female drill press operator is using a chuck key to remove the drill bit. Women right before the war had been trained on machinery as youths with a defined age range as documented by the University of California Berkeley website The Living New Deal, of 16-24 year-olds then 16-25 year-olds.[109] Exploration of the topic of how many young women had prior training before accepting positions in factories in response to WWII could offer more insight about women and machinery.

The drill press is one of the least complicated pieces of equipment to run and is easily broken down into simple steps on how to operate. The main challenge of using a drill press would be changing out a dull drill bit. With a can of oil and a cleaning rag at her side, the operator turns a chuck key to loosen the jaws of the chuck, releasing the bit. The Camelback drill, named for its humped design trimmed out of Wright's image, runs slower and due to the enormous weight of the machine, it is prone to less vibration and lower noise levels. Minus the safeguards of modern drills, like Rosener's press operator, the moving parts are visible and a safety hazard. Similar to most equipment, maintenance is a necessity, and the Camelback requires daily and weekly oiling. These drills were predominantly utilized for drilling large holes as their bulk allows the table to hold heavier pieces.

[109] https://livingnewdeal.org/glossary/national-youth-administration-nya-1935/

Wright achieves a dynamic balance between woman and machine, the shadows cast bring a dramatic effect to image as the machine is as much an integral part of photograph as the operator. Her concentration on her hands with a deep focus on the drill creates a more powerful statement of her understanding than cheerily smiling for the camera.

Where Gabain's hazy lithograph provided a glimpse into the workshops of lathes designed for mass production, Laura Knight reveals another side of machining. Bright colors contrast sharply from the industrial setting of Gabain's workers when compared to *Ruby Loftus Screwing a Breech Ring* (1943, Figure 20) operating her lathe as captured by Knight. Another firmly established artist, Knight, was made Dame of the British Empire in 1929 and was only the second woman since its founding in 1769 to become a member of the Royal Academy in 1927.[110]

For the First World War she was approached for a commissions by the British government about the Canadians stationed at Camp Witley in England. Knight produced a painting of Joe Shears, a bantam-weight boxing champion that she titled, *Physical Training at Witley Camp*.[111] But it was with the Second World War that she was offered short term contracts, and determined her own commission price to the War Artist Advisory Committee (WAAC) before documenting the achievements of the numerous

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[110] Laura Knight, *The Magic of a Line; The Autobiography of Laura Knight* (London: William Kimber, 1965), 194.

[111] Janet Dunbar, *Laura Knight* (London: William Collins Sons & Co Ltd, 1975), 95-98. This painting is in the collection of the Canadian War Museum in Ottawa.

women who were conscripted for the war effort.[112] As a distinguished artist, Knight designed a recruitment poster for the Women's Land Army, completed portraits of award winning female officers and painted the scenes of women supporting the war as cooks or toiling at barrage balloon repairs.[113]

In *Ruby Loftus Screwing a Breech Ring,* Loftus is using an Engine Lathe for cutting the metal that will eventually become a breech ring. Since this is heavier than a Capstan Lathe seen in use by Gabain's operator, the boring bar moves slower due to the lathe's size which makes it an ideal tool for producing larger works that required a skilled machinist. Loftus stares intently as the bit cuts away material which is illustrated in refined detail from the oil splashing off the large yellow round face of the lathe instead of a chuck attached to the spindle. Knight sketched Loftus for a whole day attempting to capture the essences of what the young woman had accomplished.[114]

Loftus exemplified the precision required of a machinist in order to execute a breech ring. Working with exact tolerances of between 0.010 and 0.025 inches on a specially machined metal surface called an interrupted or sectored thread. This sophisticated part was incised with a conical tapered internal threads on one end of the block tube which differed significantly from the other side which was cut as straight threads.[115] This complex process required measurements at each step and reconfiguring

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[112] Palmer, *Women War Artists*, 85.

[113] Barbara C. Morden, *Laura Knight A Life* (Pembroke Dock, UK: McNidder & Grace, 2014), 208-210.

[114] Morden, *Laura Knight A Life, 215.*

[115] U.S. Army Materiel Development and Readiness, *Engineering Design Handbook Series Breech Mechanism Design* (Alexandria, VA: 1979), 1-17 – 1-20.

of the lathe to accomplish each of the individual cuts. Loftus was 21 years-old at the time and a tobacconist's assistant prior to learning how to machine sections out of a block of steel in order to create the intermittent sections of threaded area that are vital for the breech ring to work effectively.[116]

She achieved mastery of this intricate machining process within two years, unheard of during this time as the normal rate of competency prior for the men had been eight to nine years.[117] So accomplished was Loftus that the men from the Woolwich Arsenal protested and send a delegation of 26 men to verify her expertise. They learned that according to the Inspection Department, the female machinist return rate or amount of errors in the shop was "less by a good percentage" when the numbers were comparted to Woolwich.[118]

The breech ring is one of two components of the breech required for the heavy caliber weapons that were used against aircrafts, and the other is the breechblock carrier. These two parts were located at the base of the gun where the ammunition was loaded into the barrel of the firearm and sealed. The breechblock was a cylindrical block of metal, similar to a plug, that was screwed into the end of the breech ring that sealed the backend opening of the barrel. The breech ring served as a connector between the barrel

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[116] Rosie Broadly, *Laura Knight Portraits* (London: National Portrait Gallery Publications, 2013), 92.

[117] Broadly, *Laura Knight Portraits, 92.* Broadly states that the training Loftus mastered had taken the men eight to nine years but Morden states seven to eight. Due to the many misconceptions about this painting that I have found in Morden's book, I am inclined to the time frame used by Broadly, which is further supported by other sources.

[118] Dunbar, *Laura Knight,* 162.

and the breechblock. Knight included in her paining above Loftus' back an upright silver cylinder with single cut threads in a large dark square container that could easily pass as the barrel of the anti-aircraft autocannon. The Bofors 40mm gun used a threaded barrel that was screwed into the breech ring on one side and the carrier was locked in place on the back side using an interrupted screw.[119]

What makes Loftus' ability to machine this complex ring so unique was that she understood that precision measurements necessary for the ring to effectively seal the breech when the other two parts of the weapon were attached. Several writers however have misread the painting or misconstrued Knight's explanations. Author Brian Foss attempts to say that Knight failed to show Loftus' skill because he misunderstood the breech ring, calling the item Loftus is working on a breech block, which is a separate component. He also mislabeled a 40mm anti-aircraft weapon as a double-barrel, and then spelled out 40mm exhibiting a misuse of standard terminology when discussing caliber.[120]

The pitch or space between the threads are of vital importance when dealing with fasteners as this specific way of cutting the threads kept the breech block from opening due the force of pressure when the shells were ignited.[121] Patience and skill contributed to Loftus' success as meticulous calculations were required when machining as the tools under her left hand testify as Knight included these vital instruments. Barbara Morden in *Laura Knight, A Life* comments on a machinists "tools of the trade, a spanners", yet there

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[119] Morden, *Laura Knight A Life,* 212.

[120] Brian Foss, *War Paint Art, War, State and Identity in Britain 1939-1945* (London: Yale University Press, 2007), 111.

[121] U.S. Army, *Engineering Design Handbook Series Breech Mechanism Design,* 1-12.

are no spanner wrenches in the painting.[122] On the bed of the lathe are other tools required for exact assessment, a short handled dark grey box-end wrench for tightening the adjustment bolts on the lathe, near the wrench are additional gauge blocks for checking dimensions. An inside caliper hanging off over the slide that verifies the circumference. Closer to Loftus is an ivory handled burr whip which removes burrs and sharp edges that are caused during the manufacturing process. Morden also asserts that there is a "workbench" which Loftus leans over in the painting, which is an improperly identified cross slide and apron of the lathe.

The Engine Lathe in the painting corresponds closely with the Swift brand yet with the view from rear of the lathe, the brand is indistinguishable. The details are enough to identify the type of lathe by the dark gray tailstock in the lower left hand corner. It gleams from oil that falls on the enamel surface like the slides directly in front of the tailstock which reflect back the lamp light in the pools of oil. Morden speaks of sparks flying from the lathe, which is inconsistent with the machining process and would be considered a safety hazard.[123] Since oil was required for lubrication, cooling, and washing away metal particles, I am uncertain how a spark could even appear in such a wet environment.[124]

Loftus' long blue sleeves are rolled and pushed up along with a waist apron for safety holding her clothes away as the lathe spins at a high rate of speed that could easily

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[122] Morden, *Laura Knight A Life,* 212.

[123] Morden, *Laura Knight A Life,* 212.

[124] Knight, *The Magic of a Line; The Autobiography of Laura Knight*, 284. Knight speaks of when she had visited Skefko's ball-bearing shop where there were sparks, which is a completely different process that uses grinding whereas Loftus is machining.

catch any loose items. Loftus has her hair tied up in a net which further protects her hair from becoming caught in the rotating lathe. Loftus' coveralls have patches of oil flung on them that would have soaked into the material producing areas of discoloration to the cloth. Author Rachel Aspden discusses Loftus in *War through Women's Eyes* as wearing "paint-splattered… overalls." There is oil being "splattered" around from the lathe but not paint, I believe this observation lacks any grounding in an actual machine shop environment as oil is a common element found within any machining setting.[125]

There is one man who would be considered the shop foreman who would act as a supervisor and assist with questions from the women. This "token man", as called by Morden, was common in the factories as an overseer of the skilled labor force that is found in any workshop, independent of the gender of the employees.[126] Including him among the less skilled women, Knight demonstrated an understanding of the hierarchy that often happens in industrial spaces. Such an important detail aids in distinguishing Loftus from those women in the background, though their attire corresponds to hers, they are using bench lathes for less complex grinding and polishing work. The highly skilled Loftus is partitioned away by the dark brown carts from the other women as she mills the complicated interrupted screw cut spotlighted by her intense stare and bright work light.

Knight painted on site for three weeks which may have influenced her inclusion of a background feature of the metal grids on the windows that protect the glass in case of flying parts or materials. Her experience with Loftus was documented by Janet Dunbar in

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[125] Rachel Aspden, "War Through Women's Eyes," *New Stateman* 138, no. 4940 (March 2009): 44-46.

[126] Morden, *Laura Knight A Life,* 212.

Laura Knight, noting that while on site painting, a wheel flew by Knight who then realized the danger inherent in a factory setting as she threw her body over her canvas to protect it.[127] Yet Foss fails to correctly identify this important piece of safety equipment in the painting, calling the metal grids "venetian blinds."[128] Having blinds in a manufacturing area is inconsistent with the interior of any plant that requires bright light during the whole production process along with the fact that items are often accidently hurled about the area.

The success of *Ruby Loftus Screwing a Breech Ring* was a testament to Knight's ability to portray a skilled women as this painting was the main focal point at the Imperial War Museum opening in 1943 and voted Picture of the Year.[129] Yet criticisms abound that the painting was only propaganda and once the detractors were proven wrong, then remarks solely about Loftus femininity became the focus, the male gaze dismissing the accomplishment of a talented young women.[130] Knight's familiarity with the machining process demonstrated in her painting illustrates that she captured Loftus' expertise more effectively using a paint brush than a whole paragraph of words would accomplish.

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[127] Dunbar, *Laura Knight,* 20.

[128] Foss, *War Paint Art,* 111-112.

[129] Alice Strickland, *Laura Knight* (London: Eiderdown Books, 2019), 42.

[130] Foss, *War Paint Art,* 111-112.

CONCLUSION

Mechanics has long been an area dominated by men due to the misconception that women lacked the capacity to fully understand the complex nature of machines. Women who dared to enter those masculine dominated areas of mechanical knowledge were subjected to intense scrutiny compared to their male counterparts. A major barrier excluding women from technology was the specialized language spoken by those in the industry. Comparable to learning any new dialect, immersion has been proven the most effective, since it constantly surrounds the student with the material. Few opportunities exist for women to participate in a mechanical dialogue in a safe space. The male assumption is that technology is too complex or difficult for women and they would lose interest in the conversation once the concepts of torque and gear ratios are discussed. Women who have challenged this long held belief have found that being of mediocre competence is the quickest way to become dismissed by the industry. The bar is set the highest for women, they must prove that they are better than the best to garner acceptance.

Challenging this false notion is an uphill battle women contend with everyday in the mechanical world. I spent over twenty years fighting the prejudices inherent in the automotive field. Proving with each class and every training seminar that I was worthy of my Master Automotive Technician ASE certification thorough the percentage of correct diagnosis and the ability to articulate the depth of my mechanical knowledge. Unfortunately, my experience is the same as many women who sought to become educated in all facets of the machine and wish to be valued for their skill instead of their gender.

Women's interest in the mechanical world started to rise exponentially with the introduction of the automobile, which was auspicious as their skills became instrumental with the onset of World War I. With nations calling the men to battle, industrial jobs needed workers to supply the munitions, and fill in non-combat roles such as transportation. Women became trained en masse on equipment that had previously only been handled by men. Female drivers volunteered to assist with communications and movement of the wounded, often with their own vehicles. This unprecedented involvement of both genders was seen as historic as British and Canadian governments sought to gain their support through the use of artists. Mostly male artists were commissioned but women were considered skilled enough to employ as photographers, painters and printmakers. Unlike their male counterparts, female artists were expected to record events behind the lines and at the home front in the factories. These women took their assignments a step further. Edis recorded the female drivers working on their ambulances while Stevens, May and Airy showcased the skillset of the women machinists who ran lathes.

When the Great War ended, governments began rebuilding, infusing the infrastructure with funds that created marvels of architecture and machinery. U.S. artist Driggs rendered the monumental structures like temples to modernity while capturing the essence of the airplane all in the Precisionist style. She was joined in her reverence for machinery by Delaunay who used her theory of Simultanism to portray the inner workings of the Spitfire airplane engine, the V-12 Merlin, then the Constant Speed Propeller in colossal murals that explained in technical detail their function in the language of color.

When the world was once again engulfed in conflict as World War II forced countries to mobilize their able-bodied men for combat, women rallied to support the war by entering the workforce to train as machinists, in mechanical repair, and welding. Both British and American administrations remembered the value of documenting the non-combatant roles from the last war and commissioned artists with providing visuals to the public. Photographers Bonney and Roesner both snapped pictures of well dressed women operators highlighting their skill with drill presses. Bonney utilized her connections as an American who had networks all through Europe to present women training on engines. Rosener traveled to U.S. ports to photograph welders in portrait-like poses. Gabain's prints rendered the skilled but tidy women machining parts on a large lathe and the refreshing crispness of a female operator sitting at her machine deftly working. Besides governments, private companies showed their support as *Life* contracted Reindel to capture the women in shipyards as they contributed their newly acquired welding skills to the cause with less emphasis on their womanhood.

Researching female artists employed by the U.S. to document the war, I came across Barbara Wright who had over 2600 images in the Library of Congress of women during the New Deal and WWII. While combing the sources available, I noticed the lack of representation of women artists of color in the U.S., the UK and Canada. A photograph for the New Deal during 1941 of a young women changing a bit on a drill by Wright was missing details about the artist. The only information I could find about Wright was in conjunction with a Swiss lesbian photojournalist Schwarzenbach who spent considerable

time with her leading me down a path of inquiry if Wright's data was purposefully left out due to her possible sexuality.

The British commissioned one of their greatest female painters, Laura Knight to create portraits of award winning women and uplift the spirits of the public with her work. Knight studied Ruby Loftus as she ran a lathe to manufacture one of the most complex parts of a weapon, the breech ring. With tight tolerances and complicated cuts designed, if successful, to safeguard the gun operators. Knight illustrated her skill so effectivity that there was debate among male machinists if this female operator actually existed. Once her detractors were defeated, the male gaze took over and attempted to devalue Loftus' knowledge by focusing on her looks instead of her competence. Knight's documentation of Loftus skill was so detailed in her description it was undeniable in its accuracy.

Women previously prevented by societal norms from fully immersing in the mechanical world were captured by female artists as they exhibited their skills in utilizing machines in support of the war effort throughout both WWI and WWII. Interacting with workers, artists became knowledgeable of a device's operation, learning from the laborers who used the equipment on a daily basis and through direct observation. Capturing the essence of the machine by providing details such as the correct geometric configuration demonstrated an understanding far beyond common knowledge as the works created illustrate how these ladies defied this seemingly male-only prerogative that the technological dialect is for them alone.

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