HAY EQUIVALENT PRODUCED UTILIZING BIO-DIESEL EQUIPMENT TO REMOVE MOISTURE CONTENT BY SCREW EXTRACTION: A PILOT STUDY

by

Curtis O. Burns

An Abstract
of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Technology University of Central Missouri

April, 2013
ABSTRACT

by

Curtis Burns

Producing quality hay in the Midwest with its unreliable weather is problematic. Failure to remove significant moisture content during drying results in moldy hay. Feeding such hay to animals is dangerous. Farmers owning both silage and bio-diesel production equipment could cut and transport grasses from the field to the bio-diesel screw extractor. The proposed hay production method is the direct cutting and removal of grass from the field to a screw extractor where hay equivalent at less than twenty percent moisture is produced for storage as winter feed. This study investigated and tested the moisture extraction ability of the screw extractor owned by UCM, by utilizing various moisture levels of grass as feed stock (simulating farmers’ field conditions). This pilot study achieved hay flake with less than twenty percent moisture content, but only once during this limited pilot study. Further testing is required to validate this alternate hay production method.
HAY EQUIVALENT PRODUCED UTILIZING BIO-DIESEL EQUIPMENT TO REMOVE MOISTURE CONTENT BY SCREW EXTRACTION: A PILOT STUDY

by

Curtis O. Burns

A Thesis presented in partial fulfillment of the requirements for the degree of Master of Science in the School of Technology University of Central Missouri

April, 2013
HAY EQUIVALENT PRODUCED UTILIZING BIO-DIESEL EQUIPMENT
TO REMOVE MOISTURE CONTENT BY SCREW EXTRACTION:
A PILOT STUDY

by

Curtis Burns

April, 2013

APPROVED:

Thesis Chair: Doctor Ronald Woolsey

Thesis Committee Member: Doctor Kyle Lovercamp

Thesis Committee Member: Doctor Jeff Ulmer

ACCEPTED:

Chair, School of Technology: Doctor Doug Koch
Dean, Graduate School:

UNIVERSITY OF CENTRAL MISSOURI
WARRENSBURG, MISSOURI
ACKNOWLEDGEMENTS

This research was supported by a Willard North Research Award for Graduate Students. I would like to thank Mr. William Whitby, Tool Center Manager of University of Central Missouri (UCM); for his assistance in assembling the screw extractor. I would also like to thank my thesis committee for their helpful guidance.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>ix</td>
</tr>
<tr>
<td>CHAPTER 1: NATURE AND SCOPE OF THE STUDY</td>
<td>1</td>
</tr>
<tr>
<td>Statement of Problem</td>
<td>7</td>
</tr>
<tr>
<td>Purpose of Study</td>
<td>7</td>
</tr>
<tr>
<td>Research Questions</td>
<td>8</td>
</tr>
<tr>
<td>Research Hypotheses</td>
<td>8</td>
</tr>
<tr>
<td>CHAPTER 2: REVIEW OF LITERATURE</td>
<td>9</td>
</tr>
<tr>
<td>Equipment</td>
<td>9</td>
</tr>
<tr>
<td>Alternate Production of Hay</td>
<td>11</td>
</tr>
<tr>
<td>Dangers</td>
<td>12</td>
</tr>
<tr>
<td>Hay Flake Usage</td>
<td>12</td>
</tr>
<tr>
<td>CHAPTER 3: METHODOLOGY</td>
<td>14</td>
</tr>
<tr>
<td>Specimens</td>
<td>14</td>
</tr>
<tr>
<td>Instruments and/or Apparatus Used</td>
<td>15</td>
</tr>
<tr>
<td>Statistical Analysis</td>
<td>23</td>
</tr>
<tr>
<td>Research Plan</td>
<td>23</td>
</tr>
<tr>
<td>Time-on-task</td>
<td>24</td>
</tr>
<tr>
<td>CHAPTER 4: RESULTS</td>
<td>26</td>
</tr>
<tr>
<td>Analysis</td>
<td>30</td>
</tr>
<tr>
<td>Hypothesis Statement</td>
<td>33</td>
</tr>
<tr>
<td>Table</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------</td>
<td>------</td>
</tr>
<tr>
<td>1. Time-on-task</td>
<td>25</td>
</tr>
<tr>
<td>2. Collected Data</td>
<td>30</td>
</tr>
<tr>
<td>3. Descriptive Statistics</td>
<td>31</td>
</tr>
<tr>
<td>4. Correlation</td>
<td>32</td>
</tr>
<tr>
<td>5. ANOVA</td>
<td>32</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figures</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hay making in the 1500’s</td>
<td>2</td>
</tr>
<tr>
<td>2. In-field hay stack</td>
<td>3</td>
</tr>
<tr>
<td>3. Large round hay bales</td>
<td>4</td>
</tr>
<tr>
<td>4. Wrapped hay bale for Haylage</td>
<td>5</td>
</tr>
<tr>
<td>5. Chopping and loading grass for Haylage</td>
<td>6</td>
</tr>
<tr>
<td>6. Selected Plot</td>
<td>14</td>
</tr>
<tr>
<td>7. Fescue, pre-cut close-up</td>
<td>15</td>
</tr>
<tr>
<td>8. Screw Extractor pre-assembly</td>
<td>16</td>
</tr>
<tr>
<td>9. Design CAD drawing</td>
<td>16</td>
</tr>
<tr>
<td>10. Finished Screw Extractor in use</td>
<td>17</td>
</tr>
<tr>
<td>11. Externally assembled Cage</td>
<td>18</td>
</tr>
<tr>
<td>12. Cage inserted into partially assembled frame</td>
<td>19</td>
</tr>
<tr>
<td>13. Front side of Ring Nut</td>
<td>19</td>
</tr>
<tr>
<td>14 Backside of Ring Nut showing internal bevel</td>
<td>20</td>
</tr>
<tr>
<td>15. Screw with Threaded Adjustment Insert and Handle</td>
<td>21</td>
</tr>
<tr>
<td>16. Screw Extractor adjustment handles</td>
<td>22</td>
</tr>
<tr>
<td>17. Hay flake output</td>
<td>28</td>
</tr>
<tr>
<td>18. Non-hay flake output</td>
<td>28</td>
</tr>
<tr>
<td>19. Outside of removed cage (three bars)</td>
<td>35</td>
</tr>
<tr>
<td>20. Inside of removed cage (three bars)</td>
<td>35</td>
</tr>
</tbody>
</table>
CHAPTER 1: NATURE AND SCOPE OF THE STUDY

To supply feed to ruminants and hindgut fermenter animals during inclement and/or winter weather, a farmer stores grass from the growing season until needed. Cutting the grass and allowing it to lie on the ground in sunny weather to dry is the traditional way of making hay. This is problematic because weather is unreliable, rain, clouds, and ground moisture may slow drying; having enough days of good weather is critical in making quality hay by this method.

From a study by Henning and Wheaton (1993):

When hay is baled, it should not be higher than 18 to 22 percent moisture. At higher levels of moisture, bales lose large amounts of dry matter … caused by excessive heating and molding …. In severe cases, spontaneous combustion is possible. Failure to achieve and maintain proper moisture levels during hay production permits spoilage; feeding spoiled hay contaminated with mold is dangerous to the health of animals (Casteel, Rottinghaus, Johnson, & Wicklow, 1995).

Successful production of hay in central Missouri is fraught with difficulties, primarily because farmers are dependent on good weather. Wet weather during hay production can lead to unacceptable hay quality.
With appropriate equipment a farmer can affect the drying rate of the grass, e.g. crimping the grass to speed up the drying rate when initially cut (Henning & Wheaton, 1993), or artificially drying the grass with supplemental heat (Muller, Cruywagen, du Toit, & Botha, 2008). Cutting, drying the grass and getting the hay into storage before weather damages the hay is an ongoing concern for farmers. Historically, hay production was a labor intensive activity. The whole family was needed to cut, gather, and put the hay into storage before the weather changed. This was only possible if the farm families were large enough; otherwise, hay production became a community activity.

Presently, hay production uses special machinery to reduce costs, improve quality, and transport hay quickly to storage or market. The cost for this machinery is justified by the saving in manpower expenses, i.e. how many employees are required to produce hay and what one individual can accomplish during the hectic hay production time frame.
The cost of this specialized equipment, both in capital and maintenance expenditures, has driven innovation in hay production methods. As companies produce competitive haying equipment, innovative machines and methods drive the marketplace. This started with the progression from loose hay, requiring barns with large hay lofts or field stacks, to machine cut and baled hay (Simpson, 2009).

Cut hay bales allow a greater amount of hay to be stored in the same space as loose hay. Baled hay is divided into small or large bales. This division is by weight. Large bales weighing up to 3,000 pounds (Hires, 1991) require machinery to handle, and small bales are of a size and weight that are human manageable (80 pounds). Predominantly, large hay bales are of two competitive types: round and cubic. Large round hay bales do not require protective storage; their water-shedding shape has acceptable levels of deterioration when stored outside. Whereas cubic bales which can measure four by four by eight feet require protective storage.
The following brief discussion will not cover all possible alternates to hay production, but several variations will be highlighted. Traditional silage is green corn that is cut and placed into a silo; using grass instead of corn creates haylage, a reduced cost substitute. Silage is highly palatable to animals as feed, but construction of the silo to produce and store silage is costly. The feeding value between silage types is comparable (Byers, 1965). A relativity new method to make haylage is to plastic wrap a large bale (achieving “air tight” fermentation) as compared to fermentation and storage in a silo. When the farmer has not invested capital in a silo and harvesting equipment, the process of wrapping large bales in a plastic wrap allows bag silage to be a cost effective option (Clarke, 2001); but the disadvantages, initial cost and the disposal of the plastic wrap, requires careful consideration.
Similar harvesting equipment can be used for both corn silage and haylage. The cost of growing grass for haylage is less than the cost of growing corn: cheaper seed bed preparation, less chemicals, simpler planting requirements, plus less cost and amount of fertilizer (Barnett, 2006). The forage harvesters which cuts and reduces the length of the plant require different feeding attachments for corn and grass. The forage harvester also loads the cut material into silage wagons for transport to storage. An alternate proposal is to use the screw extractor to remove moisture from the grass when transported from the field as a cost effective alternate method to haylage or hay production.
Farm-grown oil crops used to make bio-diesel, for the farmers own use or to sell in the marketplace, can use a screw extractor for oil extraction. This is accomplished by squeezing the seeds of oil crops until the oil flows out of one section and the de-oiled residue (oilcake) exits the other end of the extractor. Farmers would utilize the screw extractor for oil extraction after the oil seed harvest. Good business practices encourage capital equipment to be fully utilized throughout the year, i.e. using screw extractor in off season for grass moisture extraction.

Grass growth rates are affected by weather, ground moisture, hours of sunlight, and grass genetics. The leaves of the plant are what is harvested for animal consumption. Initial energy for re-growth of grass leaves cut from the plant comes from energy stored in the crown and roots of the grass. Once the leaves have re-grown, replenishment of stores for the crown and roots is by photosynthesis of the re-grown leaves. When energy from the leaves has filled the energy stores, then the plant can start its sexual plant growth for reproduction, i.e. flowers and seeds.
Harvesting of grasses before sexual growth, flowers and seeds, achieves more leaves than stems, resulting in high quality hay (Stichler, 2002). The greatest growth rate of grass in central Missouri is during the spring, which, generally speaking, is also the wettest season. Spring also has the least number of acceptable hay production days (Massey, Carpenter & Gerit, 2007).

Statement of Problem

Producing quality hay in the Midwest with its unreliable weather patterns during the haying season is risky. Damaged hay is expensive to farmers, both due to equipment costs expended in production and replacement cost of winter-animal feed.

Purpose of Study

The proposed alternate hay production method, the direct removal of grass from the hay field to a screw extractor for moisture removal, requires testing of the screw extractor ability to remove moisture from grass. Operationally, farmers owning both silage and bio-diesel production equipment could use this equipment to cut and transport grass from the field to the screw extractor. Moisture extraction from grass would be in a sheltered, out of the weather, location. This pilot study investigated the possibility of this alternate method of hay production. The method does not produce traditional hay bales or haylage but a dense grass residue called “hay flake” in this study. This hay flake can be stored until winter and then used by farmers as an effective method of dealing with unreliable Midwest weather. This study tested the moisture extraction ability of the screw extractor, owned by the University of Central Missouri (UCM), to produce hay flake. The study specifically addressed operational configurations required to efficiently process grass with the screw extractor.
The pilot used various moisture levels of cut grass as feed stock, simulating farmers’ field conditions, to attempt moisture reduction below twenty percent. The moisture content of input (plant material) and output (hay flake) was recorded for calculation and analysis.

Research Questions

1. Can UCM’s screw extractor reduce moisture content of grass below twenty percent moisture content in a single pass?

2. Can a screw extractor used for oil extraction for bio-diesel production also be used for hay flake production?

Research Hypotheses

H₀₁: There will be no statistically significant relationship between the hay flake moisture content and the extraction screw settings.

Hₐ₁: There will be a statistically significant relationship between the hay flake moisture content and the extraction screw settings.
Preserving grass as hay, for feeding animals during the winter, is traditionally the preferred method as being the least costly method. Production of high quality hay is fraught with difficulties; the greatest being the need for good weather to allow cut grass to cure (dry) in the sun when lying on the ground. The frequent loss of the entire hay crop to the weather has inspired multiple approaches in preserving grass for winter feed.

Equipment

Standing grass must first be cut; originally this task was done by hand. The industrial revolution brought about mechanical equipment for grass cutting; the sickle bar mower where cutting teeth cycle between finger segments all mounted on a bar was first horse drawn and then tractor mounted. The sickle bar mower requires sharpening of the cutter teeth often and easily clogs during use. An improvement has been to mount spinning disks, driven by tractor power, with cutting teeth onto a bar; this makes sharpening/changing teeth easy and the disk mower is self-clearing of jams. To improve the speed that the cut grass dries the stems can be crushed to expose the internal moisture to the drying environment. This process is performed by a machine called a crimper; recently both the mower and crimper have been incorporated into one, called a conditioner. After being cut the grass lays on the ground for sun drying. The upper side of the grass pile receives the full sun whereas the bottom is shaded and is in contact with the ground moisture; turning the partially dried hay over allows complete drying (Simpson, 2009).
The problem is that if the hay is too dry, the leaves, the most nourishing part, will shatter and be lost. Originally, dried hay was raked and piled loosely into the hay loft of a barn. The dry hay must be raked into rows that are collected and baled at a controlled moisture level (Henning & Wheaton, 1993). Turning the hay over when on the ground is by rakes; whereas, spreading the hay out to dry if rained upon is by tedders. Hay balers collect and increase the density of dry grass, from loose hay to dense hay bales. The current trend is for larger sized bales to achieve cost efficient hay transport; large hay bales allow efficient long distance trucking (Mooney, 2011). Hay production is primarily baling costs: that is, the expense of equipment plus consumable costs. The consumables, i.e. plastic twine and net wrap, must survive outdoor storage i.e. be non-biodegradable; disposal have become an environmental problem in rural America. Also, this plastic must be removed before feeding, otherwise cattle can eat the plastic which is detrimental to their health (Anderson, 2008).

Ensilage is the art of storing wet plant material in a controlled environment, usually in strongly constructed silos. This method is expensive because of the cost of: silos, harvesting, and feeding equipment; thus corn is normally used because of its better cost to feed efficiencies. A new process is to “bag” silage where wet baled hay is plastic wrapped to achieve an air-tight bag; by passing the costs of a physical silo. The study by Clarke (2001) addresses safety and benefits of a bagged silage system. The possible feeding values of ensilage and hay were studied by Byers (1965) and Brown, Hillman, Lassiter, & Huffman, (1963). The type of silage harvesting equipment employed affects the silage process.
From Pauly and Lingvall, (1999) study, damaging the plant cell walls releases food for lactic acid bacteria growth improving the quality of silage. The extraction of moisture by screw extraction would rupture the cell walls (Lu, Jorgensen and Barrington (1980). The study by Richter, Fricke, & Wachendorf, (2010) removed grass moisture content by a screw extractor, producing a pressed fluid and a press cake. The press fluid was used to produce biogas in a digester, and the press cake was dried producing a solid fuel. Some of the biogas was needed to dry the press cake, e.g. initial moisture levels of the press cake were above twenty percent, to permit storage of the press cake and pressing improved efficiencies of the burning process.

Pelletizing or cubing of plant materials is another harvesting method, but the cost to pelletize feed is costly because of specialized equipment and material required. In Gilbert, Ryu, Sharifi, & Swithenbank’s (2009) study they show that pressing “saw grass” into pellets can be problematic, “moisture content …was found to have a significant impact on pellet quality” (Gilbert et al., 2009). Using grass with its low feed value as the input is normally not cost-efficient; commercial pelletized animal feed is a value-added product fortified with supplemental ingredients to create a balanced feed ration. Using only grass in a pelletized supplement creates an expensive product without the balanced feed benefit.

Alternate Production of Hay

Muller, Cruywagen, du Toit, and Botha, in their 2008 study, found artificially dried alfalfa hay to be equivalent (in feed value) to sun cured hay during good weather.
The extra cost of artificially drying hay, fuel costs have increased since this study was conducted, is not justified, unless wet weather is encountered during harvest. Morissette, and Savoie, (2008) study provides a cost estimate for artificial drying hay. Their study used baled hay instead of loose hay as in Muller’s et al. (2008) study. The moisture content of the baled hay was twenty-six percent, which was then reduced to twelve percent. This study baled wilted grass, requiring good weather to wilt and bale. This study did not address baled hay higher than twenty-six percent moisture content grass.

Dangers

The ability to artificially dry grass ensures hay without mold but at an added cost. In their 1995 study, Casteel, Rottinghaus, Johnson, and Wicklow show that poorly produced hay which often had mold hidden inside of the bale leads to waste (rejected hay) or animal sickness. Hallas, et al. (2009) traced scrapie infection to high moisture hay production methods as practiced in French and Spanish Basque regions. These studies illustrate the importance of proper moisture reduction during hay production.

Hay Flake Usage

In Lu, Jorgensen and Barrington (1980) study, cut alfalfa was made into hay or silage. Samples for testing were produced by: artificially drying for hay, directly ensilage, cell macerated and then dried, macerated and then pressed once or twice before drying, ensilage and then repressed. In this study the moisture levels of samples pressed – once or twice – were not reduced to less than twenty percent.
One recommendation from this study was “Increasing the intensity of extraction to obtain an optimum dry matter” (Lu, et al., 1980), also “When the fibrous residues were handled as hay, digestibility of fiber components was increased by cell maceration” (Lu, et al., 1980). From Mogensen, Ingvartsen, Kristensen, Seested, & Thamsborg (2004) study, they examined three types of supplementary feed while roughage was provided by silage and grass pellets feed ad libitum. This study had no problems with usage of grass pellets. Depending on biomass inputs: straw, woody plants, grass, garbage, and what is now considered waste streams would produce dry combustible fuel for sustainable energy production (Wachendorf, Richter, Fricke, Grab, & Neff, 2009).
CHAPTER 3: METHODOLOGY

Specimens

Hay is composed of dried mixed grasses, legumes, and weeds. This mixture may be of one component or equally/unequally divided in composition, if only one component is predominant it is said to be a “solid stand.” For this study a ninety-five percent fescue stand was used. The specimens were collected from the researcher’s property and harvested from selected plots to maintain high fescue mixtures.

Figure 6. Selected Plot. Burns, C. Creative Commons Attribution Share Alike 3.0 Unported.
Instruments and/or Apparatus Used.

University of Central Missouri’s (UCM) screw extractor and its components were located in storage at the T.R. Gaines Technology Complex (TRG). This screw extractor was designed to press oil from bio-oil crops for production of bio-diesel, see Figure 8. UCM has the ability to produce bio-diesel for experimental testing and academia usage.
A suitable frame and belt safety shields were designed with Computer Aided Design (CAD) software by the researcher see Figure 9.
The frame and auxiliary mounts were constructed from generated designs. The screw extractor and all auxiliary components were installed onto the frame; the electrical system was designed and installed to create an operational screw extractor. Funding support was from the Willard North Research Award for Graduate Students. The assembled screw extractor was used to remove moisture content from the samples.

The screw extractor subassembly has a frame in which a driven flighted screw rotates. One end is driven by a gearbox, which itself is driven by drive belts powered by a three phase 5 horsepower electrical motor.
The “solids output” in this type of screw extractor is between the gearbox and the flighted screw section. The “liquid outputs” are the center section of the frame, containing the “cage” of “bars” surrounding the flighted section of the internal screw; this is where compression of plant material separates liquid from the solids. The input of the extractor is a funnel for feeding plant material into the start-of-the-flighted section of the internal screw. The last section is the adjustment section, where a “threaded insert” positions the internal screw inside of the frame. The cage is a set of machined bars that form a segmented tube that the internal screw operates inside of, see Figure 11; note the bars are assembled outside of the extractor for illustration proposes only.

Figure 11. Externally assembled Cage. Burns, C. Creative Commons Attribution Share Alike 3.0 Unported.

In Figure 12 the cage of bars has been installed in the frame, but without the “ring nut” installed.
The ring nut (Figure 13) has two purposes, one is to hold the bars inside of the frame; two it is the backside of the “clearness space.” The clearness space is the distance between the flighted section of the screw and the backside of the ring nut (Figure 14, inside bevel) where the material is compressed to separate the liquids from the solids.
The compression adjustment subassembly consists of: the threaded insert and its handle, pictured in Figure 15, removed from the body of the screw extractor and attached to the flighted screw, which is screwed into the frame positioning the flighted screw for operation and the “lock ring” (see Figure 16) used to secure the adjustment during operation. The ring nut is screwed into the opposite end of the frame providing a restriction against which the compression for extraction is developed.
Starting on the rightside of Figure 15 the adjustment cross-handle, painted silver, is used to turn the threaded insert. The threaded insert is on the left of the handles in the picture, the next section of the screw is the flights of the screw. The flighting section of the screw has a core expansion located at the end, where the final high compression work is accomplished. In the picture this section is the “bulge” where the flighting disappears, before the drive section. The drive section is the last section of the extractor’s screw, far left in the picture. The backside of this bulge is one half of the clearness space that the threaded insert adjusts, i.e. the distance between bulge and ring nut.
Plant material progresses down the flights, being pressed against the inner surface of the cage until encountering the bulge, where the grass is forced against the ring nut; through the adjustable clearness space before finally exiting the screw extractor between the inner surface of the ring nut and the power driven section of the screw (drive shaft of gear box); the last section of the screw pictured at the extreme far left. Figure 16 shows the screw extractor assembled: the internal screw, bars within cage, ring nut secured inside of the frame, and threaded insert screwed into the outside of the assembled frame, the silver cross-handles are used to turn the threaded insert, and silver ring with handle is to lock adjustment settings.

Figure 16. Screw Extractor adjustment handles. Burns, C. Creative Commons Attribution Share Alike 3.0 Unported.
The weight of all samples, before and after extraction, was recorded for each run. The data recorded allowed Dry Matter (DM) content to be calculated for the input material (grass) and output material (hay flake) per run. The process of calculating the DM is to dry samples in an oven until weight change from evaporation reaches a stable minimal weight. Hay flake and input grass samples were dried using a microwave oven (Steevens, Belyea, and Crawford, 1993), and weighed with UCM’s digital scale located in UCM’s automotive laboratory. A string trimmer was used to harvest the grass plots.

Statistical Analysis

An analysis of amount of moisture removed by screw extractor was used to determine if $H_1$ should be rejected. The software program MS Excel was used to find descriptive statistics and $F$ from t testing; furthermore, this study used an $F_{\text{significance}}$ of 95% confidence (1.96) in calculations.

Research Plan

A literature review was performed to assess current practices of hay production. This pilot study tested the feasibility of a screw extractor removing moisture from grass to produce hay equivalent. Different operational adjustments of extraction effort were tested. Grass samples were collected from selected plots using a string trimmer. The cut grass was transported to UCM TRG building for processing; this commute (30 minutes) allowed the grass to wilt, a reduction of moisture content. The screw extractor was pre-adjusted per run, for a preplanned extraction compression level. Because the screw extractor of UCM has a funnel intake, designed for feeding oil bearing seeds, this mandated manual feeding of samples.
Warning, the process of hand feeding the screw extractor is a hazardous process, “Serious personal injury possible.” The cut grass was hand fed into the extractor; output samples were collected after the screw extractor had “loaded up” with grass. The extraction process requires that a plug of plant material accumulate inside the clearance space of the extractor before any output is created, as indicated by juice exiting solid output until this plug is created. Samples of the cut grass was collected before each run and a sample of output (hay flake) was used to calculate the DMs. Comparison between input DM and output DM indicates the moisture percentage removed in extraction. The samples were weighed before being dried in a microwave oven (researcher’s personal equipment), and then again after reaching a stable minimal weight. The output (hay flake) DM was calculated and compared to recommended moisture levels by Henning and Wheaton (1993). The formula to calculate DM is (wet sample weight - weight of sample container) subtract (dry sample weight - weight of sample container) then divide by (wet sample weight - weight of sample container) which is multiplied by 100 to convert to a percentage. The percentage of moisture removed per run, at a pre-set adjustment, demonstrated the ability of UCM’s screw extractor to preserve cut grass as hay flake. The DM per adjustment was used to make an overall judgment of this proposed hay production method. Data from the runs was used to find the F for the Hypothesis, reject/fail to reject, decision.

Time-on-task

The study was completed in less than a year. The steps of each run controlled the time and number of runs completed for this study.
Each run entails: cutting grass, collection and transport, weighing/drying a sample of the cut grass before extraction, extraction of moisture, weighing/drying a sample of the hay flake, recording weights, disassemble and cleaning of the extractor. Also the re-growth rate of the grass plots affected this study, in that; new grass plots were required because of drought during study.

Table 1

<table>
<thead>
<tr>
<th>Task</th>
<th>Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idea germination</td>
<td>Jan 15 – Jan 30</td>
</tr>
<tr>
<td>Literature review</td>
<td>Feb 1 – March 30</td>
</tr>
<tr>
<td>Computer Aided Design (CAD)</td>
<td>April 1 – May 1</td>
</tr>
<tr>
<td>Construction of frame</td>
<td>May 2 – Aug 20</td>
</tr>
<tr>
<td>Assembly of screw extractor</td>
<td>Jul 2 – Aug20</td>
</tr>
<tr>
<td>Collection of grass/extraction of moisture</td>
<td>Aug 21 – Sep 1</td>
</tr>
<tr>
<td>Analysis</td>
<td>Sep 1 – Oct 1</td>
</tr>
<tr>
<td>Report generation</td>
<td>Sep 1 – Feb 28</td>
</tr>
</tbody>
</table>

*Note: Construction and assembly of frame was an iterative process.*
The procedure to create hay flake was to cut selected grass with a string trimmer then hand collect grass for transport to UCM’s T.R. Gaines Technology Complex (TRG), where the screw extractor was stored. There was some grass moisture lost during transport, wilting of grass during the 30 minute commute. Digital Scale NEXUS N-2000 was checked out of the TRG tool room, and the screw extractor was moved outside, where the extraction was performed. A sample of the cut grass was collected and weighed before it was dried and reweighed to permit input Dry Matter (DM) to be calculated. Preliminary, grass was fed into the screw extractor until the clearness space of the screw extractor was filled, indicated when liquid stopped flowing out of the solids exit. Once a sample amount of hay flake was generated and collected, the run was stopped. This sample was weighed, dried, and reweighed to permit output DM to be calculated. Because the screw extractor’s adjustment could not be set while the clearness space is full of grass, the extractor was required to be disassembled and cleared. Also the extractor could not be reassembled unless all grass residues was removed. Because of the limited clearness space inside of the extractor, the cage of bars could not be installed if they were fouled. During extraction the extractor becomes “hot”, caused by the energy consumed in compression of the grass, and the liquid being extracted would start to boil (warning - hot liquid was expelled during usage “spitting” personal safety equipment required).
The disassembly, cleaning, and reassembly of the extractor during this study normally required two hours – hot metal of the extractor required cool down, to allow hand reinstallation of the cage into the extractor’s frame – before the next extraction run could be started. This pilot study completed eight extraction runs before the study was stopped for safety/liability reasons; raw data collected during this study is presented in Appendix A. The adjustment setting was set by completely closing the gap between the screw bulge and backside of ring nut – metal to metal contact – and then backing out the number of turns required. The adjustment is approximate, adjustment handle has a 1/8 (ratio of one turn) slop, a design/manufacturing tolerance issue.

Weights of samples are in grams: input and output tare (bowl), wet (before extraction), dry (after extraction). The calculated DMs are percentages, \[\frac{(\text{tare-wet}) - (\text{tare-dry})}{\text{tare-wet}} \times 100\]. Note run seven has weight modified to permit DM calculations i.e. (10 grams added to both: Out wet and Out dry). Also run one and two did not produce any output (hay flake). Run five adjustment setting was out of this study’s range. Observe, that run eight Out DM is the only one to achieve a reduction in moisture content below twenty percent; the study’s standard. Also run eight was the only run that produced hay flake (see Figure 17) as output. The output that resembled corn flakes (Figure 17) was a visual indication of a good production run; that is, a low moisture content and acceptable grass throughput. Figure 18 is an example of non-hay flake output having moisture content of roughly thirty percent.
Figure 17. Hay flake output. Burns, C. Creative Commons Attribution Share Alike 3.0 Unported.

Figure 18. Non-hay flake output. Burns, C. Creative Commons Attribution Share Alike 3.0 Unported.
Adjustment settings were varied from \( \frac{1}{2} \) to 10 turns during testing. With adjustment setting less than one (see Table 2) extractor failed to produce an output. The clearness gap between the screw’s bulge and the ring nut’s inside bevel was too small for passage of material; on disassembly clearness space was discovered to be full of compacted material resembling thick bond paper. One turn of the adjustment handle was used for pre-testing; for various reasons procedure failed to produce output DM, e.g. exhaustion of grass supply before output production, interruption of run, inflammation of sample. Note drying of sample with microwave requires close attention to temperature of sample to prevent damage. Not more than one minute of microwave power was possible between weightings during this study. Initial assumption during testing was that less than one turn would produce hay flake, whereas, not until more than one turn was attempted did screw extractor produce hay flake. One and 1/8 setting was set and Output DM was calculated during disassembly of extractor before next run. This calculation drove the next setting of one and 1/16 turns for the last run of this pilot study. The ten turn adjustment was an error in procedure – failed to set correct adjustment after reassembly – this adjustment setting is a magnitude outside the interest area of the study. The adjustment screw is manufactured with 19 threads, whereas, less than 2 threads on the end are of interest in this study.
Table 2

Collected Data.

<table>
<thead>
<tr>
<th>Run #</th>
<th>Adjustment</th>
<th>Input DM (%)</th>
<th>Output DM (%)</th>
<th>Temperature (F)</th>
<th>Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/2</td>
<td>76.2</td>
<td>0.0</td>
<td>74</td>
<td>67</td>
</tr>
<tr>
<td>2</td>
<td>3/4</td>
<td>76.5</td>
<td>0.0</td>
<td>76</td>
<td>67</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>74.4</td>
<td>23.7</td>
<td>74</td>
<td>67</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>74.5</td>
<td>40.8</td>
<td>76</td>
<td>67</td>
</tr>
<tr>
<td>5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10</td>
<td>75.5</td>
<td>34.2</td>
<td>67</td>
<td>79</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>72.0</td>
<td>35.8</td>
<td>67</td>
<td>79</td>
</tr>
<tr>
<td>7</td>
<td>1+1/8</td>
<td>75.4</td>
<td>33.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>50</td>
<td>94</td>
</tr>
<tr>
<td>8</td>
<td>1+1/16</td>
<td>76.7</td>
<td>12.5</td>
<td>50</td>
<td>94</td>
</tr>
</tbody>
</table>

*Note:* Adjustment is number of turns of the adjustment screw. Out tare is weight of empty sample container in grams. Out wet is weight of container and processed sample of wet hay flake in grams. Out dry is weight of container and dried hay flake in grams. Out DM is calculated Dry Matter content of hay flake (Steevens, Belyea, and Crawford, 1993) a percentage. RH is Relative Humidity a percentage. Temp is outdoor Temperature in Fahrenheit. In tare is empty sample container in grams. In wet is sample of grass and container in grams. In dry is sample of dried grass and container in grams. In DM is calculated Dry Matter content of grass (Steevens, Belyea, and Crawford, 1993) a percentage.

<sup>a</sup>Run 5 adjustment setting was outside of study’s range. <sup>b</sup>had 10 grams added to Out wet & Out dry to permit Output DM calculation.

Analysis

The collected data was analyzed in Microsoft Excel using the statistical plugin; lack of the dataset’s N, (only 5 data points available) did not yield sufficient variability to test for significant significance.
The following: descriptive statistics (Table 3), correlation (Table 4), and ANOVA (Table 5) were calculated using the 5 runs that provided measurable output with a range of adjustable setting of the screw extractor’s gap adjustment collar. The adjustments were measured in turns. Several runs used setting that produced no measurable result.

Table 3

<table>
<thead>
<tr>
<th>Adjustment</th>
<th>Input DM (%)</th>
<th>Output DM (%)</th>
<th>Temperature (F)</th>
<th>Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.04</td>
<td>74.60</td>
<td>29.28</td>
<td>63.40</td>
</tr>
<tr>
<td>Median</td>
<td>1.00</td>
<td>74.50</td>
<td>33.60</td>
<td>67.00</td>
</tr>
<tr>
<td>Mode</td>
<td>1.00</td>
<td>N/A</td>
<td>N/A</td>
<td>50.00</td>
</tr>
<tr>
<td>SD</td>
<td>0.05</td>
<td>1.54</td>
<td>10.06</td>
<td>11.34</td>
</tr>
</tbody>
</table>

*Note: count of runs was 5

* 0.05
Table 4

### Correlation

<table>
<thead>
<tr>
<th></th>
<th>Adjustment</th>
<th>In DM</th>
<th>Out DM</th>
<th>Humidity (%)</th>
<th>Temperature (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjustment</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In DM</td>
<td>0.600</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Out DM</td>
<td>-0.202</td>
<td>-0.629</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humidity (%)</td>
<td>0.856</td>
<td>0.506</td>
<td>-0.424</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Temperature (F)</td>
<td>-0.886</td>
<td>-0.591</td>
<td>0.484</td>
<td>-0.992</td>
<td>1</td>
</tr>
</tbody>
</table>

Because of the small number of samples taken in this study insufficient data exists to determine a significant relationship between the study variables.

* 0.05

Table 5

### ANOVA

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F crit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>22614.826</td>
<td>4</td>
<td>5653.707</td>
<td>59.750</td>
<td>7.711E-11</td>
<td>2.866</td>
</tr>
<tr>
<td>Within Groups</td>
<td>1892.461</td>
<td>20</td>
<td>94.623</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 0.05
Hypothesis Statement

From the ANOVA, with a P value that is less than Alpha (0.05) and an F that is larger than F critical would tend to support the notion to reject the null hypothesis “H₀₁: There will be no statistically significant relationship between the hay flake moisture content and the extraction screw settings” and accept the alternate hypothesis, “Hₐ₁: There will be a statistical significant relationship between the hay flake moisture content and the extraction screw settings.”

However, with a lack of sufficient data points to give a definite statistical confidence level no decision can be made.

Research Questions

The study’s first research question ask if the University of Central Missouri’s screw extractor would reduce moisture content of grass to below twenty percent in a single pass?

H₀₁: μ < .20

The answer is a reserved yes; with only one run producing hay flake at less than twenty percent, more runs duplicating this ability is required to definitely answer this question as a positive. This pilot did produce hay flake at less than twenty percent, but most runs were roughly thirty percent.

The second research question was whether the screw extractor used for oil extraction in bio-diesel production could also be used for hay flake production? While the results may support that the extractor could be used to produce hay flake insufficient data exists in this study to formulate a conclusion.
CHAPTER 5:
SUMMARY DISCUSSION AND RECOMMENDATIONS

Summary of the Study and Results

The collected data was analyzed in Microsoft Excel using the statistical plugin and was found to be inconclusive because of insufficient data – only 5 data points available – to give a definite statistical answer to the research hypothesis. This pilot study did produce hay flake, but only once. The ten turn adjustment run was an error in procedure – failed to set correct adjustment after reassembly – this adjustment setting is a magnitude outside of the interest area of this study. The output DM for a single turn adjustment run was approximately thirty percent, which is approximately the same for 10 turns, e.g. also thirty percent. Thus, a magnitude of difference in the midrange of the possible adjustment of the screw extractor has minor effect; whereas, the adjustment of the screw extractor at the extreme edge has a major effect. This screw extractor has an adjustment screw that is manufactured with 19 threads; whereas, less than the last 2 threads are of interest to this study. As this study was cut short and did not produce enough data points to create a statistical relevant answer, but the results do point to possible future paths of study.

Observations

An observation was that the clearness gaps machined into the bars that construct the internal cage of the screw extractor allowed solid material to escape through to the liquid exit. Removal of this additional clearness gap would presumably reduce the amount of solids in the liquid extract; this would also affect the oil extraction functionality.
This extra machined clearness space also caused problems when the extractor was disassembled. The bars of the cage and the assembled cage in the frame were “glued” together, e.g. plant material bonded the metal parts together. This required physical scrapping the grass residue off to allow the cage to be dislodged from the frame. In Figure 19 notice that the gaps between bars is filled with extruded material. Plus the clear bands visible are caused by the frame blocking extruded material exit, this trapping of material between the frame and the bars plugged the liquid exit during extraction.

Figure 19. Outside of removed cage (three bars). Burns, C. Creative Commons Attribution Share Alike 3.0 Unported.

In Figure 20 the machined clearness space is filled with plant material, visible as a greenish line between bars, plus some long fibers of grass “fuzz” hangs down inside the cage (facing the viewer in this figure).

Figure 20. Inside of removed cage (three bars). Burns, C. Creative Commons Attribution Share Alike 3.0 Unported.
Note in Figure 10 the liquid exits – elongated slots above the yellow bucket – are filled with this material; the green mass visible in the frame’s liquid exit slots. Also visible is the grass in the input funnel (yellow) and solid output in catchment trough (just left and above of the yellow bucket).

The extra machined cleanness space of the bars filled at an unknown rate during this study, this plugging of the cleanness space affected the passage of liquid and solids through the extractor. Theoretically this could explain the varied Out DM’s of the three runs with one turn as the adjustment setting. The exact compression pressures developed inside of the screw extractor because the adjustment setting is unknown; but adequate internal extraction pressure is indicated by “flake” production. The screw extractor output that resembled corn flakes was a visual indication of a good production run (Figure 17), e.g. a low moisture content and acceptable grass throughput of the screw extractor.

Recommendations for Further Study

The internal cage is made of the “hex bars” alternating with the “rectangle bars” to create the outer constraint that plant material is pressed against by the screw motion, i.e. the inter surface of the cage and the outer surface of the screw trap plant material and compresses the material to extract moisture or oil. The rectangle bars have machined “cleanness gaps” along their sides. The gaps are located between the hex bars and the rectangle bars when the cage is assembled in the frame. These cleanness gaps allow solid plant material to pass between the bars of the cage and exit out of the extractor in the liquid section.
These gaps reduced the compression effort applied to the plant material reducing efficiencies; that is, amount of oil extracted without contamination from soybeans and the moisture removed from grass. This extractor’s machining of the current bars is not uniform; replacing these bars with constant machined bars for the cage would remove a source of process variance in the extraction process.

The elimination of the machined clearness space between bars would affect the compression pressure developed and the flow paths inside the extractor. The plant material filling the currently machined clearness space between bars is unpredictable; reducing the gap between bars by eliminating the machined clearness space, should reduce extraction process variance. This modification would also provide an approximation of extraction performance change when bars become worn, e.g. the operational wear of clearness between bars, as compared to new bars.

One design difference of some screw extractors is that the screw is fixed and the ring nut is adjustable; the adjustment is with an adjustable output ring collar, not an adjustable screw as with this study’s extractor. Some of these adjustable ring collars screw extractors have an adjustable pressure system controlling the amount of compression developed inside the screw extractor; i.e. hydraulic or pneumatic cylinders forcing collar against plant material advancement through the screw flights. This adjustable pressure system would give researchers a proportional pressure monitoring ability of the internal extraction effort developed inside the screw extractor; whereas, the adjustment setting of present screw extractor is an approximation of compression effort developed inside of the UCM’s screw extractor.
Discussion

The current industrial practice for oil extraction of oil crops is to extract the oil by machinery before solvent extraction; mechanical extraction achieves roughly thirty percent oil extraction with the rest removed by solvent extraction. Hexane, a byproduct of oil refining. When oil was cheap so was hexane, but future costs of oil will encourage greater usage of mechanical extraction of oils. This pilot study hints at the ability of screw extraction to remove greater amounts of oil from crops than currently practiced.

Switch grass is being tested as a fuel source for co-generation of power. The advantage of switch grass is its low input requirements (fertilizer, pesticides) and ability to utilize poor quality land (marginal cropland because of erosion potential). One of the problems discovered in testing has been the deterioration of the grass in storage, e.g. fuel storage beyond the growing season. In the Wachendorf, Richter, Fricke, Grab, & Neff (2009) study, the solid fuel produced from grass required artificial drying to overcome this problem. Also this study found that extraction process benefited the combustion process by removing minerals from the solid fuel. This pilot study’s extraction of moisture content from grass to below twenty percent would allow storage of the “fuel flake” without deterioration until consumed in a boiler and would improve the value of it as an alternative fuel by removing minerals detrimental to combustion.

The initial premise was that a successful pilot study would indicate improved capital utilization of underutilized bio-diesel equipment, e.g. improved return on capital investment correlating to improved equipment efficiencies. Because good business practices encourage capital equipment to be fully utilized throughout the year.
Using oil extraction equipment for hay flake production during the growing season provides a better return on invested money. Also Barnett’s (2006) study found that when farmers establish grass as a crop in a crop rotation plan, the erosion control and soil conditions were improved. From the Morissette & Savoie (2008) study, which provided a cost estimate for artificially drying hay, but their study, used baled hay instead of loose hay as in the Muller, Cruywagen, du Toit, & Botha (2008) study. The moisture content of the baled hay was twenty-six percent, which was then reduced to twelve percent. Morissette & Savoie (2008) study used wilted grass which required good weather to permit the wilting and baling; this study did not address higher than twenty-six percent moisture content grass being baled. The electrical energy consumed during moisture extraction by the screw extractor should compare favorable to the energy consumed by baling and artificially drying of hay.

Lu, Jorgensen, & Barrington (1980) found that macerate of grass improved digestibility. Hay flake production would macerate grass cell walls during the extraction process, thereby increasing its digestibility and winter feed desirability. Mogensen, Ingvartsen, Kristensen, Seested, & Thamsborg’s (2004) study examined three types of supplementary feed while roughage was provided by silage and grass pellets feed ad libitum; this study had no problems in usage of grass pellets (compacted grass product). The potential substitution of hay flake for grass pellets as roughage in animal feed would assume no problem as both are composed of compressed grass.
A lesson learned in this pilot study is that the motor of the screw extractor needs to be reversible, thus allowing unloading of the internal spaces of grass. The extractor cannot be disassembled and cleaned while packed with grass residue.

This pilot study indicates that the initial selection process for a screw extractor which includes hay/fuel flake production and bio-diesel production needs be considered before purchase of equipment.
REFERENCES


Appendix A

Raw Collected Data

<table>
<thead>
<tr>
<th></th>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
<th>Run 4</th>
<th>Run 5&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Run 6</th>
<th>Run 7</th>
<th>Run 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjustment</td>
<td>½</td>
<td>¾</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td>1</td>
<td>9/8</td>
<td>17/16</td>
</tr>
<tr>
<td>Out tare (gram)</td>
<td>15.4</td>
<td>15.4</td>
<td>15.2</td>
<td>15.5</td>
<td>14.9</td>
<td>15.0</td>
<td>15.1</td>
<td>15.4</td>
</tr>
<tr>
<td>Out wet (gram)</td>
<td>23.7</td>
<td>16.0</td>
<td>19.0</td>
<td>28.0</td>
<td>64.6</td>
<td>52.4</td>
<td>30.0</td>
<td>29.0</td>
</tr>
<tr>
<td>Out dry (gram)</td>
<td>-</td>
<td>-</td>
<td>18.1</td>
<td>22.9</td>
<td>47.6</td>
<td>39.0</td>
<td>25.0</td>
<td>27.3</td>
</tr>
<tr>
<td>Out DM (%)</td>
<td>-</td>
<td>-</td>
<td>23.7</td>
<td>40.8</td>
<td>34.2</td>
<td>35.8</td>
<td>33.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.5</td>
</tr>
<tr>
<td>RH (%)</td>
<td>67.0</td>
<td>67.0</td>
<td>67.0</td>
<td>79.0</td>
<td>79.0</td>
<td>94.0</td>
<td>94.0</td>
<td></td>
</tr>
<tr>
<td>Temp (F)</td>
<td>74.0</td>
<td>76.0</td>
<td>74.0</td>
<td>76.0</td>
<td>76.0</td>
<td>67.0</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>In tare (gram)</td>
<td>15.1</td>
<td>15.2</td>
<td>15.6</td>
<td>14.7</td>
<td>15.3</td>
<td>15.3</td>
<td>15.2</td>
<td>15.4</td>
</tr>
<tr>
<td>In wet (gram)</td>
<td>49.6</td>
<td>49.6</td>
<td>39.0</td>
<td>39.8</td>
<td>36.5</td>
<td>50.0</td>
<td>38.8</td>
<td>39.0</td>
</tr>
<tr>
<td>In dry (gram)</td>
<td>23.3</td>
<td>23.3</td>
<td>21.6</td>
<td>21.1</td>
<td>20.5</td>
<td>25.0</td>
<td>21.0</td>
<td>20.9</td>
</tr>
<tr>
<td>In DM (%)</td>
<td>76.2</td>
<td>76.5</td>
<td>74.4</td>
<td>74.5</td>
<td>75.5</td>
<td>72.0</td>
<td>75.4</td>
<td>76.7</td>
</tr>
</tbody>
</table>

Note: Adjustment is number of turns of the adjustment screw. Out tare is weight of empty sample container in grams. Out wet is weight of container and processed sample of wet hay flake in grams. Out dry is weight of container and dried hay flake in grams. Out DM is Dry Matter content of hay flake calculated as a percentage \( \frac{[(\text{wet-tare})-(\text{dry-tare})]}{\text{wet-tare}} \times 100 \) (Steevens, Belyea, and Crawford, 1993). RH is Relative Humidity as a percentage. Temp is outdoor Temperature in Fahrenheit. In tare is empty sample container in grams. In wet is sample of grass and container in grams. In dry is sample of dried grass and container in grams. In DM is calculated Dry Matter content of grass (Steevens, Belyea, and Crawford, 1993).

<sup>a</sup>Run 5 adjustment setting was outside of study’s range. <sup>b</sup>had 10 grams added to Out wet & Out dry to permit Output DM calculation.
Creative Commons Attribution 2.0 License

Attribution 2.0

CREATIVE COMMONS CORPORATION IS NOT A LAW FIRM AND DOES NOT PROVIDE LEGAL SERVICES. DISTRIBUTION OF THIS LICENSE DOES NOT CREATE AN ATTORNEY-CLIENT RELATIONSHIP. CREATIVE COMMONS PROVIDES THIS INFORMATION ON AN "AS-IS" BASIS. CREATIVE COMMONS MAKES NO WARRANTIES REGARDING THE INFORMATION PROVIDED, AND DISCLAIMS LIABILITY FOR DAMAGES RESULTING FROM ITS USE.

License

THE WORK (AS DEFINED BELOW) IS PROVIDED UNDER THE TERMS OF THIS CREATIVE COMMONS PUBLIC LICENSE ("CCPL" OR "LICENSE"). THE WORK IS PROTECTED BY COPYRIGHT AND/OR OTHER APPLICABLE LAW. ANY USE OF THE WORK OTHER THAN AS AUTHORIZED UNDER THIS LICENSE OR COPYRIGHT LAW IS PROHIBITED.
BY EXERCISING ANY RIGHTS TO THE WORK PROVIDED HERE, YOU ACCEPT AND
AGREE TO BE BOUND BY THE TERMS OF THIS LICENSE. THE LICENSOR GRANTS
YOU THE RIGHTS CONTAINED HERE IN CONSIDERATION OF YOUR ACCEPTANCE
OF SUCH TERMS AND CONDITIONS.

1. Definitions
   a. "Collective Work" means a work, such as a periodical issue, anthology or encyclopedia,
in which the Work in its entirety in unmodified form, along with a number of other
contributions, constituting separate and independent works in themselves, are assembled
into a collective whole. A work that constitutes a Collective Work will not be considered
a Derivative Work (as defined below) for the purposes of this License.
   b. "Derivative Work" means a work based upon the Work or upon the Work and other
pre-existing works, such as a translation, musical arrangement, dramatization,
fictionalization, motion picture version, sound recording, art reproduction, abridgment,
condensation, or any other form in which the Work may be recast, transformed, or
adapted, except that a work that constitutes a Collective Work will not be considered a
Derivative Work for the purpose of this License. For the avoidance of doubt, where the
Work is a musical composition or sound recording, the synchronization of the Work in
timed-relation with a moving image ("synching") will be considered a Derivative Work
for the purpose of this License.
c. "Licensor" means the individual or entity that offers the Work under the terms of this License.

d. "Original Author" means the individual or entity who created the Work.

e. "Work" means the copyrightable work of authorship offered under the terms of this License.

f. "You" means an individual or entity exercising rights under this License who has not previously violated the terms of this License with respect to the Work, or who has received express permission from the Licensor to exercise rights under this License despite a previous violation.

2. Fair Use Rights. Nothing in this license is intended to reduce, limit, or restrict any rights arising from fair use, first sale or other limitations on the exclusive rights of the copyright owner under copyright law or other applicable laws.

3. License Grant. Subject to the terms and conditions of this License, Licensor hereby grants You a worldwide, royalty-free, non-exclusive, perpetual (for the duration of the applicable copyright) license to exercise the rights in the Work as stated below:

a. to reproduce the Work, to incorporate the Work into one or more Collective Works, and to reproduce the Work as incorporated in the Collective Works;

b. to create and reproduce Derivative Works;

c. to distribute copies or phonorecords of, display publicly, perform publicly, and perform publicly by means of a digital audio transmission the Work including as incorporated in Collective Works;
d. to distribute copies or phonorecords of, display publicly, perform publicly, and perform
publicly by means of a digital audio transmission Derivative Works.

e. For the avoidance of doubt, where the work is a musical composition: **Performance Royalties Under Blanket Licenses.** Licensor waives the exclusive right to collect,
whether individually or via a performance rights society (e.g. ASCAP, BMI, SESAC),
royalties for the public performance or public digital performance (e.g. webcast) of the
Work.

i. **Mechanical Rights and Statutory Royalties.** Licensor waives the exclusive right
to collect, whether individually or via a music rights agency or designated agent
(e.g. Harry Fox Agency), royalties for any phonorecord You create from the
Work ("cover version") and distribute, subject to the compulsory license created
by 17 USC Section 115 of the US Copyright Act (or the equivalent in other
jurisdictions).

f. **Webcasting Rights and Statutory Royalties.** For the avoidance of doubt, where the
Work is a sound recording, Licensor waives the exclusive right to collect, whether
individually or via a performance-rights society (e.g. SoundExchange), royalties for the
public digital performance (e.g. webcast) of the Work, subject to the compulsory license
created by 17 USC Section 114 of the US Copyright Act (or the equivalent in other
jurisdictions).

The above rights may be exercised in all media and formats whether now known or hereafter
devised.
The above rights include the right to make such modifications as are technically necessary to exercise the rights in other media and formats. All rights not expressly granted by Licensor are hereby reserved.

4. Restrictions. The license granted in Section 3 above is expressly made subject to and limited by the following restrictions:

   a. You may distribute, publicly display, publicly perform, or publicly digitally perform the Work only under the terms of this License, and You must include a copy of, or the Uniform Resource Identifier for, this License with every copy or phonorecord of the Work You distribute, publicly display, publicly perform, or publicly digitally perform. You may not offer or impose any terms on the Work that alter or restrict the terms of this License or the recipients' exercise of the rights granted hereunder. You may not sublicense the Work. You must keep intact all notices that refer to this License and to the disclaimer of warranties. You may not distribute, publicly display, publicly perform, or publicly digitally perform the Work with any technological measures that control access or use of the Work in a manner inconsistent with the terms of this License Agreement.

The above applies to the Work as incorporated in a Collective Work, but this does not require the Collective Work apart from the Work itself to be made subject to the terms of this License. If You create a Collective Work, upon notice from any Licensor You must, to the extent practicable, remove from the Collective Work any reference to such Licensor or the Original Author, as requested.
If You create a Derivative Work, upon notice from any Licensor You must, to the extent practicable, remove from the Derivative Work any reference to such Licensor or the Original Author, as requested.

b. If you distribute, publicly display, publicly perform, or publicly digitally perform the Work or any Derivative Works or Collective Works, You must keep intact all copyright notices for the Work and give the Original Author credit reasonable to the medium or means You are utilizing by conveying the name (or pseudonym if applicable) of the Original Author if supplied; the title of the Work if supplied; to the extent reasonably practicable, the Uniform Resource Identifier, if any, that Licensor specifies to be associated with the Work, unless such URI does not refer to the copyright notice or licensing information for the Work; and in the case of a Derivative Work, a credit identifying the use of the Work in the Derivative Work (e.g., "French translation of the Work by Original Author," or "Screenplay based on original Work by Original Author"). Such credit may be implemented in any reasonable manner; provided, however, that in the case of a Derivative Work or Collective Work, at a minimum such credit will appear where any other comparable authorship credit appears and in a manner at least as prominent as such other comparable authorship credit.
5. Representations, Warranties and Disclaimer

UNLESS OTHERWISE MUTUALLY AGREED TO BY THE PARTIES IN WRITING, LICENSOR OFFERS THE WORK AS-IS AND MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND CONCERNING THE WORK, EXPRESS, IMPLIED, STATUTORY OR OTHERWISE, INCLUDING, WITHOUT LIMITATION, WARRANTIES OF TITLE, MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, NONINFRINGEMENT, OR THE ABSENCE OF LATENT OR OTHER DEFECTS, ACCURACY, OR THE PRESENCE OF ABSENCE OF ERRORS, WHETHER OR NOT DISCOVERABLE. SOME JURISDICTIONS DO NOT ALLOW THE EXCLUSION OF IMPLIED WARRANTIES, SO SUCH EXCLUSION MAY NOT APPLY TO YOU.

6. Limitation on Liability. EXCEPT TO THE EXTENT REQUIRED BY APPLICABLE LAW, IN NO EVENT WILL LICENSOR BE LIABLE TO YOU ON ANY LEGAL THEORY FOR ANY SPECIAL, INCIDENTAL, CONSEQUENTIAL, PUNITIVE OR EXEMPLARY DAMAGES ARISING OUT OF THIS LICENSE OR THE USE OF THE WORK, EVEN IF LICENSOR HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

7. Termination

a. This License and the rights granted hereunder will terminate automatically upon any breach by You of the terms of this License.
Individuals or entities who have received Derivative Works or Collective Works from You under this License, however, will not have their licenses terminated provided such individuals or entities remain in full compliance with those licenses. Sections 1, 2, 5, 6, 7, and 8 will survive any termination of this License.

b. Subject to the above terms and conditions, the license granted here is perpetual (for the duration of the applicable copyright in the Work). Notwithstanding the above, Licensor reserves the right to release the Work under different license terms or to stop distributing the Work at any time; provided, however that any such election will not serve to withdraw this License (or any other license that has been, or is required to be, granted under the terms of this License), and this License will continue in full force and effect unless terminated as stated above.

8. Miscellaneous

a. Each time You distribute or publicly digitally perform the Work or a Collective Work, the Licensor offers to the recipient a license to the Work on the same terms and conditions as the license granted to You under this License.

b. Each time You distribute or publicly digitally perform a Derivative Work, Licensor offers to the recipient a license to the original Work on the same terms and conditions as the license granted to You under this License.

c. If any provision of this License is invalid or unenforceable under applicable law, it shall not affect the validity or enforceability of the remainder of the terms of this License, and without further action by the parties to this agreement, such provision shall be reformed to the minimum extent necessary to make such provision valid and enforceable.
d. No term or provision of this License shall be deemed waived and no breach consented to unless such waiver or consent shall be in writing and signed by the party to be charged with such waiver or consent.

e. This License constitutes the entire agreement between the parties with respect to the Work licensed here. There are no understandings, agreements or representations with respect to the Work not specified here. Licensor shall not be bound by any additional provisions that may appear in any communication from You. This License may not be modified without the mutual written agreement of the Licensor and You.

Creative Commons is not a party to this License, and makes no warranty whatsoever in connection with the Work. Creative Commons will not be liable to You or any party on any legal theory for any damages whatsoever, including without limitation any general, special, incidental or consequential damages arising in connection to this license. Notwithstanding the foregoing two (2) sentences, if Creative Commons has expressly identified itself as the Licensor hereunder, it shall have all rights and obligations of Licensor.

Except for the limited purpose of indicating to the public that the Work is licensed under the CCPL, neither party will use the trademark "Creative Commons" or any related trademark or logo of Creative Commons without the prior written consent of Creative Commons. Any permitted use will be in compliance with Creative Commons' then-current trademark usage guidelines, as may be published on its website or otherwise made available upon request from time to time.

Creative Commons may be contacted at http://creativecommons.org/.
Appendix B2

Creative Commons Attribution-NonCommercial 3.0 United States

CREATIVE COMMONS CORPORATION IS NOT A LAW FIRM AND DOES NOT PROVIDE LEGAL SERVICES. DISTRIBUTION OF THIS LICENSE DOES NOT CREATE AN ATTORNEY-CLIENT RELATIONSHIP. CREATIVE COMMONS PROVIDES THIS INFORMATION ON AN "AS-IS" BASIS. CREATIVE COMMONS MAKES NO WARRANTIES REGARDING THE INFORMATION PROVIDED, AND DISCLAIMS LIABILITY FOR DAMAGES RESULTING FROM ITS USE.

License

THE WORK (AS DEFINED BELOW) IS PROVIDED UNDER THE TERMS OF THIS CREATIVE COMMONS PUBLIC LICENSE ("CCPL" OR "LICENSE"). THE WORK IS PROTECTED BY COPYRIGHT AND/OR OTHER APPLICABLE LAW. ANY USE OF THE WORK OTHER THAN AS AUTHORIZED UNDER THIS LICENSE OR COPYRIGHT LAW IS PROHIBITED.

BY EXERCISING ANY RIGHTS TO THE WORK PROVIDED HERE, YOU ACCEPT AND AGREE TO BE BOUND BY THE TERMS OF THIS LICENSE.
TO THE EXTENT THIS LICENSE MAY BE CONSIDERED TO BE A CONTRACT, THE LICENSOR GRANTS YOU THE RIGHTS CONTAINED HERE IN CONSIDERATION OF YOUR ACCEPTANCE OF SUCH TERMS AND CONDITIONS.

1. Definitions

   a. "Collective Work" means a work, such as a periodical issue, anthology or encyclopedia, in which the Work in its entirety in unmodified form, along with one or more other contributions, constituting separate and independent works in themselves, are assembled into a collective whole. A work that constitutes a Collective Work will not be considered a Derivative Work (as defined below) for the purposes of this License.

   b. "Derivative Work" means a work based upon the Work or upon the Work and other pre-existing works, such as a translation, musical arrangement, dramatization, fictionalization, motion picture version, sound recording, art reproduction, abridgment, condensation, or any other form in which the Work may be recast, transformed, or adapted, except that a work that constitutes a Collective Work will not be considered a Derivative Work for the purpose of this License. For the avoidance of doubt, where the Work is a musical composition or sound recording, the synchronization of the Work in timed-relation with a moving image ("synching") will be considered a Derivative Work for the purpose of this License.

   c. "Licensor" means the individual, individuals, entity or entities that offers the Work under the terms of this License.
d. "Original Author" means the individual, individuals, entity or entities who created the Work.

e. "Work" means the copyrightable work of authorship offered under the terms of this License.

f. "You" means an individual or entity exercising rights under this License who has not previously violated the terms of this License with respect to the Work, or who has received express permission from the Licensor to exercise rights under this License despite a previous violation.

2. Fair Use Rights. Nothing in this license is intended to reduce, limit, or restrict any rights arising from fair use, first sale or other limitations on the exclusive rights of the copyright owner under copyright law or other applicable laws.

a. License Grant. Subject to the terms and conditions of this License, Licensor hereby grants You a worldwide, royalty-free, non-exclusive, perpetual (for the duration of the applicable copyright) license to exercise the rights in the Work as stated below:

b. to reproduce the Work, to incorporate the Work into one or more Collective Works, and to reproduce the Work as incorporated in the Collective Works;

c. to create and reproduce Derivative Works provided that any such Derivative Work, including any translation in any medium, takes reasonable steps to clearly label, demarcate or otherwise identify that changes were made to the original Work. For example, a translation could be marked "The original work was translated from English to Spanish," or a modification could indicate "The original work has been modified.";
d. to distribute copies or phonorecords of, display publicly, perform publicly, and perform publicly by means of a digital audio transmission the Work including as incorporated in Collective Works;

e. to distribute copies or phonorecords of, display publicly, perform publicly, and perform publicly by means of a digital audio transmission Derivative Works;

The above rights may be exercised in all media and formats whether now known or hereafter devised. The above rights include the right to make such modifications as are technically necessary to exercise the rights in other media and formats. All rights not expressly granted by Licensor are hereby reserved, including but not limited to the rights set forth in Sections 4(d) and 4(e).

4. Restrictions. The license granted in Section 3 above is expressly made subject to and limited by the following restrictions:

a. You may distribute, publicly display, publicly perform, or publicly digitally perform the Work only under the terms of this License, and You must include a copy of, or the Uniform Resource Identifier for, this License with every copy or phonorecord of the Work You distribute, publicly display, publicly perform, or publicly digitally perform. You may not offer or impose any terms on the Work that restrict the terms of this License or the ability of a recipient of the Work to exercise the rights granted to that recipient under the terms of the License. You may not sublicense the Work. You must keep intact all notices that refer to this License and to the disclaimer of warranties.
When You distribute, publicly display, publicly perform, or publicly digitally perform the Work, You may not impose any technological measures on the Work that restrict the ability of a recipient of the Work from You to exercise the rights granted to that recipient under the terms of the License. This Section 4(a) applies to the Work as incorporated in a Collective Work, but this does not require the Collective Work apart from the Work itself to be made subject to the terms of this License. If You create a Collective Work, upon notice from any Licensor You must, to the extent practicable, remove from the Collective Work any credit as required by Section 4(c), as requested.

b. If You create a Derivative Work, upon notice from any Licensor You must, to the extent practicable, remove from the Derivative Work any credit as required by Section 4(c), as requested. You may not exercise any of the rights granted to You in Section 3 above in any manner that is primarily intended for or directed toward commercial advantage or private monetary compensation. The exchange of the Work for other copyrighted works by means of digital file-sharing or otherwise shall not be considered to be intended for or directed toward commercial advantage or private monetary compensation, provided there is no payment of any monetary compensation in connection with the exchange of copyrighted works.
c. If You distribute, publicly display, publicly perform, or publicly digitally perform the Work (as defined in Section 1 above) or any Derivative Works (as defined in Section 1 above) or Collective Works (as defined in Section 1 above), You must, unless a request has been made pursuant to Section 4(a), keep intact all copyright notices for the Work and provide, reasonable to the medium or means You are utilizing: (i) the name of the Original Author (or pseudonym, if applicable) if supplied, and/or (ii) if the Original Author and/or Licensor designate another party or parties (e.g. a sponsor institute, publishing entity, journal) for attribution ("Attribution Parties") in Licensor's copyright notice, terms of service or by other reasonable means, the name of such party or parties; the title of the Work if supplied; to the extent reasonably practicable, the Uniform Resource Identifier, if any, that Licensor specifies to be associated with the Work, unless such URI does not refer to the copyright notice or licensing information for the Work; and, consistent with Section 3(b) in the case of a Derivative Work, a credit identifying the use of the Work in the Derivative Work (e.g., "French translation of the Work by Original Author," or "Screenplay based on original Work by Original Author"). The credit required by this Section 4(c) may be implemented in any reasonable manner; provided, however, that in the case of a Derivative Work or Collective Work, at a minimum such credit will appear, if a credit for all contributing authors of the Derivative Work or Collective Work appears, then as part of these credits and in a manner at least as prominent as the credits for the other contributing authors.
For the avoidance of doubt, You may only use the credit required by this Section for the purpose of attribution in the manner set out above and, by exercising Your rights under this License, You may not implicitly or explicitly assert or imply any connection with, sponsorship or endorsement by the Original Author, Licensor and/or Attribution Parties, as appropriate, of You or Your use of the Work, without the separate, express prior written permission of the Original Author, Licensor and/or Attribution Parties.

d. For the avoidance of doubt, where the Work is a musical composition:

i. **Performance Royalties Under Blanket Licenses.** Licensor reserves the exclusive right to collect whether individually or, in the event that Licensor is a member of a performance rights society (e.g. ASCAP, BMI, SESAC), via that society, royalties for the public performance or public digital performance (e.g. webcast) of the Work if that performance is primarily intended for or directed toward commercial advantage or private monetary compensation.

ii. **Mechanical Rights and Statutory Royalties.** Licensor reserves the exclusive right to collect, whether individually or via a music rights agency or designated agent (e.g. Harry Fox Agency), royalties for any phonorecord You create from the Work ("cover version") and distribute, subject to the compulsory license created by 17 USC Section 115 of the US Copyright Act (or the equivalent in other jurisdictions), if Your distribution of such cover version is primarily intended for or directed toward commercial advantage or private monetary compensation.
e. **Webcasting Rights and Statutory Royalties.** For the avoidance of doubt, where the Work is a sound recording, Licensor reserves the exclusive right to collect, whether individually or via a performance-rights society (e.g. SoundExchange), royalties for the public digital performance (e.g. webcast) of the Work, subject to the compulsory license created by 17 USC Section 114 of the US Copyright Act (or the equivalent in other jurisdictions), if Your public digital performance is primarily intended for or directed toward commercial advantage or private monetary compensation.

5. **Representations, Warranties and Disclaimer**

UNLESS OTHERWISE MUTUALLY AGREED TO BY THE PARTIES IN WRITING, LICENSOR OFFERS THE WORK AS-IS AND ONLY TO THE EXTENT OF ANY RIGHTS HELD IN THE LICENSED WORK BY THE LICENSOR. THE LICENSOR MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND CONCERNING THE WORK, EXPRESS, IMPLIED, STATUTORY OR OTHERWISE, INCLUDING, WITHOUT LIMITATION, WARRANTIES OF TITLE, MARKETABILITY, MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, NONINFRINGEMENT, OR THE ABSENCE OF LATENT OR OTHER DEFECTS, ACCURACY, OR THE PRESENCE OF ABSENCE OF ERRORS, WHETHER OR NOT DISCOVERABLE. SOME JURISDICTIONS DO NOT ALLOW THE EXCLUSION OF IMPLIED WARRANTIES, SO SUCH EXCLUSION MAY NOT APPLY TO YOU.
6. Limitation on Liability. EXCEPT TO THE EXTENT REQUIRED BY APPLICABLE LAW, IN NO EVENT WILL LICENSOR BE LIABLE TO YOU ON ANY LEGAL THEORY FOR ANY SPECIAL, INCIDENTAL, CONSEQUENTIAL, PUNITIVE OR EXEMPLARY DAMAGES ARISING OUT OF THIS LICENSE OR THE USE OF THE WORK, EVEN IF LICENSOR HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

7. Termination

a. This License and the rights granted hereunder will terminate automatically upon any breach by You of the terms of this License. Individuals or entities who have received Derivative Works (as defined in Section 1 above) or Collective Works (as defined in Section 1 above) from You under this License, however, will not have their licenses terminated provided such individuals or entities remain in full compliance with those licenses. Sections 1, 2, 5, 6, 7, and 8 will survive any termination of this License.

b. Subject to the above terms and conditions, the license granted here is perpetual (for the duration of the applicable copyright in the Work). Notwithstanding the above, Licensor reserves the right to release the Work under different license terms or to stop distributing the Work at any time; provided, however that any such election will not serve to withdraw this License (or any other license that has been, or is required to be, granted under the terms of this License), and this License will continue in full force and effect unless terminated as stated above.
8. Miscellaneous

a. Each time You distribute or publicly digitally perform the Work (as defined in Section 1 above) or a Collective Work (as defined in Section 1 above), the Licensor offers to the recipient a license to the Work on the same terms and conditions as the license granted to You under this License.

b. Each time You distribute or publicly digitally perform a Derivative Work, Licensor offers to the recipient a license to the original Work on the same terms and conditions as the license granted to You under this License.

c. If any provision of this License is invalid or unenforceable under applicable law, it shall not affect the validity or enforceability of the remainder of the terms of this License, and without further action by the parties to this agreement, such provision shall be reformed to the minimum extent necessary to make such provision valid and enforceable.

d. No term or provision of this License shall be deemed waived and no breach consented to unless such waiver or consent shall be in writing and signed by the party to be charged with such waiver or consent.

e. This License constitutes the entire agreement between the parties with respect to the Work licensed here. There are no understandings, agreements or representations with respect to the Work not specified here. Licensor shall not be bound by any additional provisions that may appear in any communication from You. This License may not be modified without the mutual written agreement of the Licensor and You.
Creative Commons Notice

Creative Commons is not a party to this License, and makes no warranty whatsoever in connection with the Work. Creative Commons will not be liable to You or any party on any legal theory for any damages whatsoever, including without limitation any general, special, incidental or consequential damages arising in connection to this license. Notwithstanding the foregoing two (2) sentences, if Creative Commons has expressly identified itself as the Licensor hereunder, it shall have all rights and obligations of Licensor.

Except for the limited purpose of indicating to the public that the Work is licensed under the CCPL, Creative Commons does not authorize the use by either party of the trademark "Creative Commons" or any related trademark or logo of Creative Commons without the prior written consent of Creative Commons. Any permitted use will be in compliance with Creative Commons' then-current trademark usage guidelines, as may be published on its website or otherwise made available upon request from time to time. For the avoidance of doubt, this trademark restriction does not form part of the License.

Creative Commons may be contacted at http://creativecommons.org/.
Appendix B3

Creative Commons Attribution Share Alike 3.0

CREATIVE COMMONS CORPORATION IS NOT A LAW FIRM AND DOES NOT PROVIDE LEGAL SERVICES. DISTRIBUTION OF THIS LICENSE DOES NOT CREATE AN ATTORNEY-CLIENT RELATIONSHIP. CREATIVE COMMONS PROVIDES THIS INFORMATION ON AN "AS-IS" BASIS. CREATIVE COMMONS MAKES NO WARRANTIES REGARDING THE INFORMATION PROVIDED, AND DISCLAIMS LIABILITY FOR DAMAGES RESULTING FROM ITS USE.

License

THE WORK (AS DEFINED BELOW) IS PROVIDED UNDER THE TERMS OF THIS CREATIVE COMMONS PUBLIC LICENSE ("CCPL" OR "LICENSE"). THE WORK IS PROTECTED BY COPYRIGHT AND/OR OTHER APPLICABLE LAW. ANY USE OF THE WORK OTHER THAN AS AUTHORIZED UNDER THIS LICENSE OR COPYRIGHT LAW IS PROHIBITED.
BY EXERCISING ANY RIGHTS TO THE WORK PROVIDED HERE, YOU ACCEPT AND AGREE TO BE BOUND BY THE TERMS OF THIS LICENSE. TO THE EXTENT THIS LICENSE MAY BE CONSIDERED TO BE A CONTRACT, THE LICENSOR GRANTS YOU THE RIGHTS CONTAINED HERE IN CONSIDERATION OF YOUR ACCEPTANCE OF SUCH TERMS AND CONDITIONS.

1. Definitions

a. "Adaptation" means a work based upon the Work, or upon the Work and other pre-existing works, such as a translation, adaptation, derivative work, arrangement of music or other alterations of a literary or artistic work, or phonogram or performance and includes cinematographic adaptations or any other form in which the Work may be recast, transformed, or adapted including in any form recognizably derived from the original, except that a work that constitutes a Collection will not be considered an Adaptation for the purpose of this License. For the avoidance of doubt, where the Work is a musical work, performance or phonogram, the synchronization of the Work in timed-relation with a moving image ("synching") will be considered an Adaptation for the purpose of this License.
b. "Collection" means a collection of literary or artistic works, such as encyclopedias and anthologies, or performances, phonograms or broadcasts, or other works or subject matter other than works listed in Section 1(f) below, which, by reason of the selection and arrangement of their contents, constitute intellectual creations, in which the Work is included in its entirety in unmodified form along with one or more other contributions, each constituting separate and independent works in themselves, which together are assembled into a collective whole. A work that constitutes a Collection will not be considered an Adaptation (as defined below) for the purposes of this License.

c. "Creative Commons Compatible License" means a license that is listed at http://creativecommons.org/compatiblelicenses that has been approved by Creative Commons as being essentially equivalent to this License, including, at a minimum, because that license: (i) contains terms that have the same purpose, meaning and effect as the License Elements of this License; and, (ii) explicitly permits the relicensing of adaptations of works made available under that license under this License or a Creative Commons jurisdiction license with the same License Elements as this License.

d. "Distribute" means to make available to the public the original and copies of the Work or Adaptation, as appropriate, through sale or other transfer of ownership.

e. "License Elements" means the following high-level license attributes as selected by Licensor and indicated in the title of this License: Attribution, ShareAlike.

f. "Licensor" means the individual, individuals, entity or entities that offer(s) the Work under the terms of this License.
g. "Original Author" means, in the case of a literary or artistic work, the individual, individuals, entity or entities who created the Work or if no individual or entity can be identified, the publisher; and in addition (i) in the case of a performance the actors, singers, musicians, dancers, and other persons who act, sing, deliver, declaim, play in, interpret or otherwise perform literary or artistic works or expressions of folklore; (ii) in the case of a phonogram the producer being the person or legal entity who first fixes the sounds of a performance or other sounds; and, (iii) in the case of broadcasts, the organization that transmits the broadcast.

h. "Work" means the literary and/or artistic work offered under the terms of this License including without limitation any production in the literary, scientific and artistic domain, whatever may be the mode or form of its expression including digital form, such as a book, pamphlet and other writing; a lecture, address, sermon or other work of the same nature; a dramatic or dramatico-musical work; a choreographic work or entertainment in dumb show; a musical composition with or without words; a cinematographic work to which are assimilated works expressed by a process analogous to cinematography; a work of drawing, painting, architecture, sculpture, engraving or lithography; a photographic work to which are assimilated works expressed by a process analogous to photography; a work of applied art; an illustration, map, plan, sketch or three-dimensional work relative to geography, topography, architecture or science; a performance; a broadcast; a phonogram; a compilation of data to the extent it is protected
as a copyrightable work; or a work performed by a variety or circus performer to the extent it is not otherwise considered a literary or artistic work.

i. "You" means an individual or entity exercising rights under this License who has not previously violated the terms of this License with respect to the Work, or who has received express permission from the Licensor to exercise rights under this License despite a previous violation.

j. "Publicly Perform" means to perform public recitations of the Work and to communicate to the public those public recitations, by any means or process, including by wire or wireless means or public digital performances; to make available to the public Works in such a way that members of the public may access these Works from a place and at a place individually chosen by them; to perform the Work to the public by any means or process and the communication to the public of the performances of the Work, including by public digital performance; to broadcast and rebroadcast the Work by any means including signs, sounds or images.

k. "Reproduce" means to make copies of the Work by any means including without limitation by sound or visual recordings and the right of fixation and reproducing fixations of the Work, including storage of a protected performance or phonogram in digital form or other electronic medium.

2. Fair Dealing Rights. Nothing in this License is intended to reduce, limit, or restrict any uses free from copyright or rights arising from limitations or exceptions that are provided for in connection with the copyright protection under copyright law or other applicable laws.
3. License Grant. Subject to the terms and conditions of this License, Licensor hereby grants You a worldwide, royalty-free, non-exclusive, perpetual (for the duration of the applicable copyright) license to exercise the rights in the Work as stated below:

   a. to Reproduce the Work, to incorporate the Work into one or more Collections, and to Reproduce the Work as incorporated in the Collections;
   
   b. to create and Reproduce Adaptations provided that any such Adaptation, including any translation in any medium, takes reasonable steps to clearly label, demarcate or otherwise identify that changes were made to the original Work. For example, a translation could be marked "The original work was translated from English to Spanish," or a modification could indicate "The original work has been modified.";
   
   c. to Distribute and Publicly Perform the Work including as incorporated in Collections; and,
   
   d. to Distribute and Publicly Perform Adaptations.
   
   e. For the avoidance of doubt:
      
      i. Non-waivable Compulsory License Schemes. In those jurisdictions in which the right to collect royalties through any statutory or compulsory licensing scheme cannot be waived, the Licensor reserves the exclusive right to collect such royalties for any exercise by You of the rights granted under this License;
ii. **Waivable Compulsory License Schemes.** In those jurisdictions in which the right to collect royalties through any statutory or compulsory licensing scheme can be waived, the Licensor waives the exclusive right to collect such royalties for any exercise by You of the rights granted under this License; and,

iii. **Voluntary License Schemes.** The Licensor waives the right to collect royalties, whether individually or, in the event that the Licensor is a member of a collecting society that administers voluntary licensing schemes, via that society, from any exercise by You of the rights granted under this License.

The above rights may be exercised in all media and formats whether now known or hereafter devised. The above rights include the right to make such modifications as are technically necessary to exercise the rights in other media and formats. Subject to Section 8(f), all rights not expressly granted by Licensor are hereby reserved.

4. **Restrictions.** The license granted in Section 3 above is expressly made subject to and limited by the following restrictions:

   a. You may Distribute or Publicly Perform the Work only under the terms of this License. You must include a copy of, or the Uniform Resource Identifier (URI) for, this License with every copy of the Work You Distribute or Publicly Perform. You may not offer or impose any terms on the Work that restrict the terms of this License or the ability of the recipient of the Work to exercise the rights granted to that recipient under the terms of the License. You may not sublicense the Work.
You must keep intact all notices that refer to this License and to the disclaimer of warranties with every copy of the Work You Distribute or Publicly Perform. When You Distribute or Publicly Perform the Work, You may not impose any effective technological measures on the Work that restrict the ability of a recipient of the Work from You to exercise the rights granted to that recipient under the terms of the License. This Section 4(a) applies to the Work as incorporated in a Collection, but this does not require the Collection apart from the Work itself to be made subject to the terms of this License. If You create a Collection, upon notice from any Licensor You must, to the extent practicable, remove from the Collection any credit as required by Section 4(c), as requested. If You create an Adaptation, upon notice from any Licensor You must, to the extent practicable, remove from the Adaptation any credit as required by Section 4(c), as requested.

b. You may Distribute or Publicly Perform an Adaptation only under the terms of: (i) this License; (ii) a later version of this License with the same License Elements as this License; (iii) a Creative Commons jurisdiction license (either this or a later license version) that contains the same License Elements as this License (e.g., Attribution-ShareAlike 3.0 US)); (iv) a Creative Commons Compatible License. If you license the Adaptation under one of the licenses mentioned in (iv), you must comply with the terms of that license. If you license the Adaptation under the terms of any of the licenses mentioned in (i), (ii) or (iii) (the "Applicable License"), you must comply with the terms of the Applicable License generally and the following provisions: (I)
You must include a copy of, or the URI for, the Applicable License with every copy of each Adaptation You Distribute or Publicly Perform; (II) You may not offer or impose any terms on the Adaptation that restrict the terms of the Applicable License or the ability of the recipient of the Adaptation to exercise the rights granted to that recipient under the terms of the Applicable License; (III) You must keep intact all notices that refer to the Applicable License and to the disclaimer of warranties with every copy of the Work as included in the Adaptation You Distribute or Publicly Perform; (IV) when You Distribute or Publicly Perform the Adaptation, You may not impose any effective technological measures on the Adaptation that restrict the ability of a recipient of the Adaptation from You to exercise the rights granted to that recipient under the terms of the Applicable License. This Section 4(b) applies to the Adaptation as incorporated in a Collection, but this does not require the Collection apart from the Adaptation itself to be made subject to the terms of the Applicable License.

c. If You Distribute, or Publicly Perform the Work or any Adaptations or Collections, You must, unless a request has been made pursuant to Section 4(a), keep intact all copyright notices for the Work and provide, reasonable to the medium or means You are utilizing: (i) the name of the Original Author (or pseudonym, if applicable) if supplied, and/or if the Original Author and/or Licensor designate another party or parties (e.g., a sponsor institute, publishing entity, journal) for attribution ("Attribution Parties") in Licensor's copyright notice, terms of service or by other reasonable means, the name of such party or parties; (ii) the title of the Work if supplied; (iii) to the extent reasonably practicable, the URI, if any, that Licensor specifies to be associated with the Work,
unless such URI does not refer to the copyright notice or licensing information for the Work; and (iv) consistent with Section 3(b), in the case of an Adaptation, a credit identifying the use of the Work in the Adaptation (e.g., "French translation of the Work by Original Author," or "Screenplay based on original Work by Original Author"). The credit required by this Section 4(c) may be implemented in any reasonable manner; provided, however, that in the case of a Adaptation or Collection, at a minimum such credit will appear, if a credit for all contributing authors of the Adaptation or Collection appears, then as part of these credits and in a manner at least as prominent as the credits for the other contributing authors. For the avoidance of doubt, You may only use the credit required by this Section for the purpose of attribution in the manner set out above and, by exercising Your rights under this License, You may not implicitly or explicitly assert or imply any connection with, sponsorship or endorsement by the Original Author, Licensor and/or Attribution Parties, as appropriate, of You or Your use of the Work, without the separate, express prior written permission of the Original Author, Licensor and/or Attribution Parties.

d. Except as otherwise agreed in writing by the Licensor or as may be otherwise permitted by applicable law, if You Reproduce, Distribute or Publicly Perform the Work either by itself or as part of any Adaptations or Collections, You must not distort, mutilate, modify or take other derogatory action in relation to the Work which would be prejudicial to the Original Author's honor or reputation. Licensor agrees that in those jurisdictions (e.g. Japan), in which any exercise of the right granted in Section 3(b) of this License (the right to make Adaptations) would be deemed to be a distortion, mutilation, modification
or other derogatory action prejudicial to the Original Author's honor and reputation, the
Licensor will waive or not assert, as appropriate, this Section, to the fullest extent
permitted by the applicable national law, to enable You to reasonably exercise Your right
under Section 3(b) of this License (right to make Adaptations) but not otherwise.

5. Representations, Warranties and Disclaimer
UNLESS OTHERWISE MUTUALLY AGREED TO BY THE PARTIES IN WRITING,
LICENSOR OFFERS THE WORK AS-IS AND MAKES NO REPRESENTATIONS OR
WARRANTIES OF ANY KIND CONCERNING THE WORK, EXPRESS, IMPLIED,
STATUTORY OR OTHERWISE, INCLUDING, WITHOUT LIMITATION, WARRANTIES
OF TITLE, MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE,
NONINFRINGEMENT, OR THE ABSENCE OF LATENT OR OTHER DEFECTS,
ACCURACY, OR THE PRESENCE OF ABSENCE OF ERRORS, WHETHER OR NOT
DISCOVERABLE. SOME JURISDICTIONS DO NOT ALLOW THE EXCLUSION OF
IMPLIED WARRANTIES, SO SUCH EXCLUSION MAY NOT APPLY TO YOU.

6. Limitation on Liability. EXCEPT TO THE EXTENT REQUIRED BY APPLICABLE LAW,
IN NO EVENT WILL LICENSOR BE LIABLE TO YOU ON ANY LEGAL THEORY FOR
ANY SPECIAL, INCIDENTAL, CONSEQUENTIAL, PUNITIVE OR EXEMPLARY
DAMAGES ARISING OUT OF THIS LICENSE OR THE USE OF THE WORK, EVEN IF
LICENSOR HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.
7. Termination

a. This License and the rights granted hereunder will terminate automatically upon any breach by You of the terms of this License. Individuals or entities who have received Adaptations or Collections from You under this License, however, will not have their licenses terminated provided such individuals or entities remain in full compliance with those licenses. Sections 1, 2, 5, 6, 7, and 8 will survive any termination of this License.

b. Subject to the above terms and conditions, the license granted here is perpetual (for the duration of the applicable copyright in the Work). Notwithstanding the above, Licensor reserves the right to release the Work under different license terms or to stop distributing the Work at any time; provided, however that any such election will not serve to withdraw this License (or any other license that has been, or is required to be, granted under the terms of this License), and this License will continue in full force and effect unless terminated as stated above.

8. Miscellaneous

a. Each time You Distribute or Publicly Perform the Work or a Collection, the Licensor offers to the recipient a license to the Work on the same terms and conditions as the license granted to You under this License.

b. Each time You Distribute or Publicly Perform an Adaptation, Licensor offers to the recipient a license to the original Work on the same terms and conditions as the license granted to You under this License.
c. If any provision of this License is invalid or unenforceable under applicable law, it shall not affect the validity or enforceability of the remainder of the terms of this License, and without further action by the parties to this agreement, such provision shall be reformed to the minimum extent necessary to make such provision valid and enforceable.

d. No term or provision of this License shall be deemed waived and no breach consented to unless such waiver or consent shall be in writing and signed by the party to be charged with such waiver or consent.

e. This License constitutes the entire agreement between the parties with respect to the Work licensed here. There are no understandings, agreements or representations with respect to the Work not specified here. Licensor shall not be bound by any additional provisions that may appear in any communication from You. This License may not be modified without the mutual written agreement of the Licensor and You.

f. The rights granted under, and the subject matter referenced, in this License were drafted utilizing the terminology of the Berne Convention for the Protection of Literary and Artistic Works (as amended on September 28, 1979), the Rome Convention of 1961, the WIPO Copyright Treaty of 1996, the WIPO Performances and Phonograms Treaty of 1996 and the Universal Copyright Convention (as revised on July 24, 1971). These rights and subject matter take effect in the relevant jurisdiction in which the License terms are sought to be enforced according to the corresponding provisions of the implementation of those treaty provisions in the applicable national law. If the standard suite of rights granted under applicable copyright law includes additional rights not granted under this
License, such additional rights are deemed to be included in the License; this License is
not intended to restrict the license of any rights under applicable law.

Creative Commons Notice

Creative Commons is not a party to this License, and makes no warranty whatsoever in
connection with the Work. Creative Commons will not be liable to You or any party on any legal
theory for any damages whatsoever, including without limitation any general, special, incidental
or consequential damages arising in connection to this license. Notwithstanding the foregoing
two (2) sentences, if Creative Commons has expressly identified itself as the Licensor hereunder,
it shall have all rights and obligations of Licensor.

Except for the limited purpose of indicating to the public that the Work is licensed under the
CCPL, Creative Commons does not authorize the use by either party of the trademark "Creative
Commons" or any related trademark or logo of Creative Commons without the prior written
consent of Creative Commons. Any permitted use will be in compliance with Creative
Commons' then-current trademark usage guidelines, as may be published on its website or
otherwise made available upon request from time to time. For the avoidance of doubt, this
trademark restriction does not form part of the License.

Creative Commons may be contacted at http://creativecommons.org/.