Mycenaean Linear B script: Records of Livestock as Source(s) of Energy in Agriculture and Transportation

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Abstract: - In the pre-mechanized era, the animals offered the required energy and traction power to agricultural work (e.g. plowing) and transport both in peaceful periods and in war operations. This presentation examines the recordings of the Mycenaean Age Linear B tablets (1450-1200 BC), from which the use of livestock and its utilization in these activities are implied. Oxen are recorded "𐀺 𐀏 𐀲 = *we-ka-ta*[1] = *ϝεργᾶται* = *workers*" (obviously used in agricultural work), horse-pulled chariots and the tack of the horses, etc. The great importance that was attributed at that time to the contribution of livestock to the economy is also emphasized by: (a) the chariot in Linear B is called "𐀂 𐀶 𐀊 = *i-qi-ja* = *ἰππία* = (*h*)*ippia*", from Greek *(h)ippos* = *horse*, namely the "pulled by horse" (vehicle), and, (b) Local deities are probably recorded: "Horse-Goddess", "Bullock-deity" and other Animal-deities. Furthermore, this article presents some individual parameters of daily life, related to animals, as recorded on the tablets. A possible efficiency comparison between the horses' and oxens may also be based on relative later measurements (e.g. of James Watt in 1782-1786 AD and modern Universities and the Food Agriculture Organization [FAO] of the United Nations).

Key-Words: - Linear B script, Linear B Tablets, Chariot tablets, horse, chariot, oxen, agriculture, transportation, Watt, pair (of animals).

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1 Prolegomena

At some point during the Neolithic era, between either 9.500-8.000 BC [[7], 158] or 8.000-7.000 BC, a major change occurred. The people changed from hunter-gatherers to farmers, settled in permanent settlements and became farmers and "domesticated" and cultivated plants, especially cereals [[41], 32]. This first, major change is called in the literature the 'Neolithic Revolution' or 'Agricultural Revolution' [[[6], 560-561]], [[76], 23: 12.000 years ago], [[53], 23: 10.000 years ago]], which was followed by a series of other revolutions that changed human history.

The life of "domesticated" people, who now remained "attached" to an area, led to the appearance of the first settlements, the appearance of which is called by some researchers "the urban revolution" -a term owed to Gordon Childe. However, according to Hodder [[41], 32] -who is based on archaeological findings and, besides, quotes Cauvin/Cauvin [[13], 45-50]- the Revolution of founding the "cities"/first-settlements preceded the Agricultural Revolution, which is identified with the appearance of land cultivation.

Moreover, "cultivation alone, without the extensive use of domesticated animals, was capable of sustaining even complex urban societies, but the so-called industrialization was achieved only thanks to the utilization of *animal power*," which led to more massive production. "It was the first phase in the successive exploitation of increasingly powerful sources of energy beyond that of human muscles. This exploitation of the power offered to man by livestock and the energy derived from it was possible only where the animals were domesticated and were not wild" [[[72], 158], cf. [71].

[1] The software of *Curtis Clark* is used for the syllabograms/fonts of Linear B (see *References*). *The Table of syllabograms of Linear B script are presented in the ANNEX A at the end, after* the References: at the crossing of *e.g.* **n** and **e** → 𐀚 = **ne**, or **d** and **i** → 𐀇 **= di.**

2 Force, Work, Energy, Power

In our everyday experience, the term *Force* is associated with the push or pull exerted by our muscles. However, in Physics it is defined in terms of the *acceleration* developed by the *mass* of an object (due to a *Force*) in an appropriate environment [[63], 83]. In the simplest case, the *Force* exerted on an object is constant over time and we define the *Work* produced by the *Force* as the product of "*Force*" *x* "*the Distance traveled*" by the *Force* and the *object* on which it is applied [[63], 132].

We define that a *Force* produces *Work* when its point of application is *displaced along* with the body on which it acts (Fig.1). This displacement, under whatever conditions it occurs, entails the production of (Mechanical) Work. *Energy* is preserved and is not destroyed (*conservation of Energy*), regardless of whether it changes forms (*dynamic*, *kinetic*, *electrical*, *thermal*, etc.); *Energy* is a most abstract idea, because it is a mathematical principle [[33], 1:4-1]: it is generally the stored capacity to produce *Work*. *Energy* is only obtained by consuming *Work*, while it can always be converted back into *Work*. Therefore, *Energy* is measured in the same units as *Work*: the *unit of Energy* is equal to '*the unit of force*' *x* '*the unit of length*' [[[90], 179], [[5], 1:116-117], [[63], 132, 141-143], [[33], 1:9-1]].

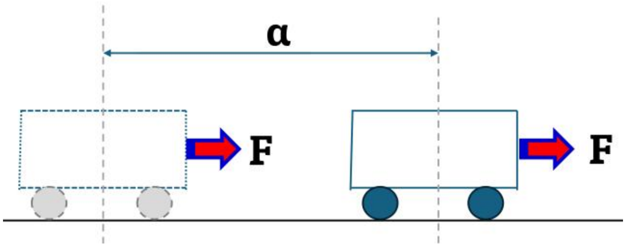

Figure 1. A *Force* (F) displacing its point of application at a *distance* (a) produces *Work = F x a*).

Power is defined as the *Energy* produced per unit of time; since there are many systems of units, the *unit of Energy* -in the International System of Units (SI)-, is defined as *1 Joule* and the *unit of Power* is defined as 1w (watt) = 1 joule/sec, which was named in honor of James Watt, of whom we will speak below; *1 joule*= 1 Nm [Newton-meter]=1kg·m^{2}·sec^{-2}, while the *metric unit* is kilogram-meter (kgm) and the English unit is the foot-pound (ft-lb)) [cf. [11], 5]. There is another *unit of Power* named 1 hp (*Horsepower*) ≈ 746 watts [[37], 175]; this *unit* originated, obviously, as an estimate of the *Power* of a *real horse*.

Therefore: (**a**) a vehicle (e.g. a chariot of the Mycenaean era) pulled by one or more horses, a caravan of donkeys or camels, has stored (*Dynamic*) *Energy*, i.e. the ability to produce *Work*; when the vehicle travels a distance *a*, *Work* is produced, which is equal to the tractive (draught) *Force* of the animals (for the sake of simplifying the calculations, considered constant over time) *x the Distance travelled* (Fig.2).

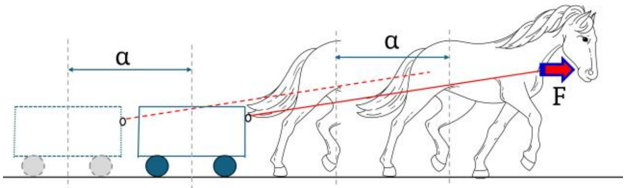

Figure 2. A horse pulling a chariot. Energy = Force (F) x Distance travelled (a).

(**b**) A pair of ploughing oxen in a field -before the ploughing work begins- also has stored (*Dynamic*) *Energy*; when the ploughing of the field is finished, the pair of oxen will have produced *Work*, which is equal to the *tractive Force of the pair of oxen* (which for the sake of simplification of calculations is assumed to be constant over time) *x the Distance travelled*.

In the following, we will examine what the Linear B tablets of the Mycenaean Palaces record about the animals used in transportation and agricultural activities (e.g. ploughing).

3 Linear B Tablets: Livestock working in Agriculture and Transportation

3.1 Tablets of Mycenaean Linear B Script

The Palatial Centers in Greece were destroyed at some era between 1400-1200/1180BC, by fires that "baked" the -contemporary to the fires- written records of the Palaces (Knossos, Pylos, Mycenae, Thebes, etc.) recorded on tablets of (raw) clay, which were recycled each one or two years. Thus, the tablets were transformed into ceramics, which have been preserved to this day. These tablets concern almost exclusively accounting records of the Palaces, at the time of their destruction(s) -the majority of them around 1200BC, with the exception of several tablets from Knossos, which date about 200 years earlier. They were written with symbols of a non-alphabetic script, which Evans, around 1900 AD, had called Linear B script; the syllabograms of the script are presented in the *Annex A* at the end of the article, after the *References*. This script was deciphered by Michael Ventris and John Chadwick in the early-1950s; it was proved to be an early form of Greek language [[86], 22], [[34], 160], [[78], 21-23], [[42], 53]].

3.2 Agriculture

The Linear B tablets contain, among other things, records of Livestock used in agricultural works, transportation and military operations. It is self-evident that the Mycenaeans exploited the strength of animals (horses, donkeys, mules and oxen) and the resulting Energy. A more detailed zooarchaeological analysis shows that, after the Neolithic era, in the Balkan Peninsula, the people managed and used animals for various purposes, including milk-production [[[36], 585-586, 573-note2], [[19], 270]; in addition, they produced cheese, obtained and used the animals' hides/leather, produced glue of animal origin and other goods [[[57], note *, 89, 87-88], [[18], 66, 69-70, 88-89, 113· σελ.88: "ivory could had glued" with a glue of animal origin "on wheels (of chariots) as a decoration"]], e.g. horns 𐀐 𐀨 𐀊 𐀠 = *ke-ra-ja-pi* from Greek *κέρας/keras*, in contrast to ivory 𐀁 𐀩 𐀞 𐀳 𐀍 = *e-re-pa-te-jo = elephanteio* [[[57], 88], [[78], 135, 341]]. Mylonas, in the craftsmen's area at the eastern wing of the Palace at Mycenae, found "a yellowish substance, which when heated turned into a strong brown colored glue"; this substance resembled "the brown matter often observed in (ivory) inlays" [[55], 425-426].

Castrated male oxen, generally tied in pairs, were the main draft animals for plows, agricultural work, and transport carts throughout the Balkan Peninsula to Crete, at least from the 2nd millennium BC onwards [[[57], 89], cf. [56]]. Since the Neolithic era, the agricultural sector produced typical Mediterranean products with a high percentage of cereals and it was considered that tillage was done by hand. At Knossos (KN86 = Ce59) pairs of ploughing oxen are mentioned in scattered centers throughout Crete and this implies ploughing with oxen [[19], 269]. 130, of the approximately 480, Palace oxen at Knossos were used for ploughing (*we-ka-ta = ϝέ-(ρ)γα-τα(ι) = workers*) [[27], 332]. It is characteristic that "working oxen" are recorded on Linear B tablets:

𐀽 𐀄 𐀐 𐀯 = *ze-u-ke-si = ζεύγεσι = pairs* (dative plural), from *ze-u-ko = *ᵈzeugos = ζεύγος (singular) [[82], 340].

𐀶 𐀃 = *qo-o = βους = ox* [[78], 48: *gᵘōns*, 195-196 ideogram, 207, 435, 577] pronounced gᵘō(n)s accusative plural of the word *βοῦς* from Sanskritic *gȧḥ*, i.e., with singular gᵘōn, in the tablet PY Cn22, where, PY=Pylos.

For oxen sacrificed as offerings to deities see [61].

𐀸 𐀏 𐀲 = *we-(r)ka-ta(i) = (ϝ)εργάται = workers* OXEN = *ideogram of ox* 6 (= 6 *oxen workers*) [[78], 212-213, KN C59, KN Ch896, where, KN=Knossos].

𐀽 = ZE, the initial syllabogram ζε/ZE of the Greek word ζεύγος/ΖΕΥΓΟΣ, that is an abbreviation for the word pair (ζεύγος) of oxen or horses (i-qo-po-qo-i-qe, from the Greek (χ)ἵππος = (h)ippos = horse + qe=και/τε [[[20], 1:196], [[82], 340: KN C 1044, 5734; Ch 896]]). It should be noted that there is no boundary in the *morphophonemic sequence* of letters in the pronounced as /kw/, which is written in Linear B as -q-, e.g. in the word ίππος (horse), 𐀂 𐀶 = i-qo = (h)ikkwos (< *ekwos) and its derivatives [[74], 1:232].

"Morphophonemics (morphophonology) in linguistics, is the study of the relationship between morphology and phonology. Morphophonemics involves an investigation of the phonological variations within morphemes, usually marking different grammatical functions; e.g., the vowel changes in "sleep" and "slept," "bind" and "bound," "vain" and "vanity," and the consonant alternations in "knife" and "knives," "loaf" and "loaves." (Britannica/Science).

The alternative forms *i-qo-po-qo-i = (h)ippophorgwoihi = (χ)ιπποφορβοί* and i-qo-po-qo-i = (h)ikkwophorgwoihi 'horse grooms, stable hostlers' (or horse breeders [[[19], 1:273], [[44], 530]]) may be a case of descending (phonetical) absorption [[74], 1:232].

When the scribes of the tablets recorded chariot horses, draft (draught) oxen, wheels (of chariots) and sometimes breastplates/thoraxes, they wrote either ZE or MO (= 𐀗) before the numbers of the measurements. The numbers following ZE vary from 1 to 462, but MO is followed only by the number 1 and is written last of all. It has been recognized that, as abbreviation, ZE represents *the pair* (*ze-u-ke-si* [= 𐀽 𐀄 𐀐 𐀯], in the tablets PY 91 = Fn 50, Fn 79, dative plural "ᵈzeuges(s)i" = ζεύγη) το δε MO = μόνος (*monwos = μονϝος, cf. Ionian μούνος, Attic μόνος = alone, sole) [[[78], 54, 593, 562], [[43], 2:1054, 2:990], [[45], 2:898-899], [[75], 1:133], [[74], 1:234], [[67], 262: *μούνος* (alone, sole) evolved to *οἶος* in *Homer*]].

The concept of pair was so important to the Mycenaeans that it was used not only for a *pair of animals* (oxen or horses) but also seems to have denoted the *area of land that a pair of oxen could plow*. We also see the Latin *iugerum* which is a singular derived from the plural *iugera*, i.e. the equivalent of *ζεύγε**α**>ζεύγ**η*** = pairs (with syneresis of ε/e and α/a to η long 'i') [[[78], 422-423], [[45], 2:899], [[68], 177, 180], [[39], 42-43]]. The Latin *iugerum* (cf. *iugum* = yoke, harnessing) is an area of land of approximately 0,25ha (the standard hectare

[ha] is 10,000 m^2 today); furthermore, the Greek word στρέμμα/stremma (1,000m^2) probably comes from the oxen's βου**στροφ**ηδόν/bou**stroph**edon *path* during plowing (*στροφ*/*στροπ*(μα)>*στρέμμα* with a turn of the *short vowel* ***ε*** to the *short vowel* ***ο***) and varied from place to place between 0,08-0,16ha (800-1.600m^2), while today it is standardized to 1.000m^2. "One stremma is equal to a strip 10m wide -the width of a sowing strip- by 100m, which is the distance at which the oxen will stop to rest," according to Nikolas, a farmer from modern Kolindros in Pieria prefecture in Greece [[39], 33-34, 39]. In Linear B, the word 𐀸𐀩𐀐 = we-re-ke (which sounded *vrek/γe*) is not interpreted with certainty but means probably *wreg/γes* (plural nom.) = "fences", "herds" (cf. Sanskrit. *vrajaḥ* = "fence, herd") [[44], 507], from which the word "βραγιά–vrag/γγa" -of the modern Greek language- should also have come. It is also characteristic that in Greece of the 1950s-1960s, in the modern vernacular of Central Greece and Thessaly[2], as in many other regions of Greece too, the expression "ζευγάρι/pair" referred to the area plowed by a pair of oxen from sunrise to sunset, i.e. approximately 80 "stremmata" [[[91], 70], [[89], 8:702], [[88], ΣΤ:3189-3190]]. Halstead presents detailed data from various regions and time periods from the Byzantine era to the 19th century: in Greece 1 "pair"/ζευγάρι of land is dependent on *many other parameters too* and it fluctuates from a very low efficiency (0,2-0,5ha/2-5 stremmata per day) to the latest one between 75-100 stremmata (7,5-10ha) with an average area of 80 stremmata (8ha) [[[39], 33-47: a thorough analysis and discussion]]. In Mycenaean Pylos the "pair"/ΖΕύγος/ΖΕυγάρι (𐀽 = ΖΕ) was probably used to measure areas granted for fodder production by the Palace of Pylos to landowners who had already borrowed Palace oxen [[38], 40].

"Oxen workers" are also mentioned in Tablets (KN Ce59) from the (*Room of the Chariot Tablets* (RCT)) at Knossos [see paragr. 3.4. below], which are the earliest Linear B tablets and date to the late-15th century BC [[[87], 29], [[24], 76, table3.2: tablets: RCT→LHIIIA1, NEP→early-LHIIIA2], [[23]], [[22]], cf. [[87], 18: absolute chronologies of the LHIIIA1-LHIIIA2 periods]; 34 oxen are recorded in five areas of Crete (Ma-sa, Da-wo, Ku-ta-to, Da-*22-to, Tylissos) and 50 in Kydonia, modern Chania. Furthermore, the tablet Kn Co907 records 91 and 13 oxen, of which 13 were sent to Knossos, while they are described as belonging to herds (*we-re-ki-ja*, *we-re-ke*, belonging to *wrejes* = enclosed spaces, see Sanskrit vrajaḥ [vraja]); see above). It seems that Kydonia, and western Crete in general, were a center of ox breeding. In other tablets from Knossos (C1044, C5734m Ch-series) the "oxen workers" are mentioned in pairs or more generally in numbers divisible by two [[[44], 2:529-530], [[43], 2:1049], [[20], 1:269], [[66], 297-298], [[26], 20]].

3.3 Transportation

In transportation, horses, donkeys [𐀃𐀜 = *o-no* = *ὄνος*] and mules [𐀁𐀖𐀍𐀜𐀂 = *e-mi-jo-no-i* = *ἡμίονοι* = mules] ([[47], 2:881, 2:887-888], [[43], 2:952]) were used, to carry cargo-loads either individually or in caravans ([[44], 2:526, 2:527: *the ideogram "HORSE" was used both for horses and donkeys*], cf. [[28], 2:709]); horses pulled chariots while oxen and mules pulled four-wheeled vehicles (carts, carriages) [[62], 817]. Moreover, animals pulled vehicles either for transport and commercial purposes (carriages, carts, several vehicles) or for military operations (chariots); chariots were also used as a display of high social status. Schon lists four overlapping uses of chariots in Mycenaean Greece [[92], 139]: military operations, bonds between members of the high aristocracy/*élite*, communication and the display of social status; however, he appears skeptical about the use of Mycenaean chariots in military operations, *notwithstanding that martial chariots are depicted in Mycenaean frescoes inside the Palaces*. In all cases, the result of their use is the same, as they increase the power of the central authority.

Horses are recorded in pairs and archaeological evidence shows that teams of two horses (pair(s)) were standard "equipment" for chariots in Late Bronze Age (LBA) Greece. The Knossos tablets (Sc-series) show that the Palace distributed to distinguished individuals/officials sets consisting of one chariot, *two thoraxes/breastplates* (*one for the warrior and one for the driver*) and two horses [[28], 2:810].

It is characteristic that in Linear B the word 𐀀𐀗 = *a-mo* = *ά(ρ)μο* renders the wheel ([[46], 2:473],[[43], 2:927], [[28], 2:756]) while the word 𐀂𐀣𐀊 = *i-qi-ja* = *(h)ippia* renders the chariot (tablets KN Sd4403, TH V159) that is the name attributed to chariot was "*drawn by horse*(*s*)" plain, while the term "vehicle" was omitted [[[62], 2:817], [[43], 2:963]].

[2] Testimonies of my father Spyros K. Giannakos (born 1916) and my father-in-law Thomas S. Saliaris (born 1920).

Furthermore, in the tablets (KN281 = Sd4402+, PY300 = Ub1315) 𐀀𐀛𐀊 = *a-ni-ja* = *(h)āniai* = *ἡνία* = *reins* (nominative plural) are mentioned cf. [Pind. ʽᾱνίαι, Att. ἡνίαι, some dialects ἀνίαι] ([[43], 2:929]), as well as other accessories. On a tablet from Thebes [TH Fq 214+] the word 𐀁𐀠𐀦𐀂 = *e-pi-qo-i* was read, i.e., the dative plural of *ep(h)ikkwoihi* = *ἔφιπποιχι* = '*to the riders*', to the horsemen (or 'to those who are charged with the care of the horses(*?*)) [[43], 2:954].

3.4 Martial Operations – Tablets of Chariots at Knossos

At Knossos several hundreds of tablets dealing with chariots were unearthed. They have been classified in large collections from the place they were found: the Arsenal, the Area of the Bull Relief, and the Northern Entrance Passage (NEP), the *Room of the Chariot Tablets* (RCT) and the Room of Column Bases (RCB). Evans, in 1904, discussed the form of vehicles, described in chariot tablets, and, after the decipherment of Linear B, Ventris/Chadwick [[78 version 1956], 361-362] presented a first approach of the texts for chariots and wheels from Knossos as well as from Pylos. In the tablets the chariots are described in three forms: wheeled chariot, wheel-less chariot and chariot frames both in Linear B and in ideograms (Figure 3-right). Approximate appearance of a Mycenaean Chariot from Mycenaean vase-paintings, from the Tiryns fresco and from the analogy of contemporary Egyptian chariot harness is depicted in Figure 3-left as Ventris/Chadwick presented. It is obvious that the wheeled chariot ideogram is very similar to the chariot's picture. In Pylos tablets, almost 200 years later (c.1200BC), only chariot wheels are described [[34], 169-170: with detailed bibliographic references].

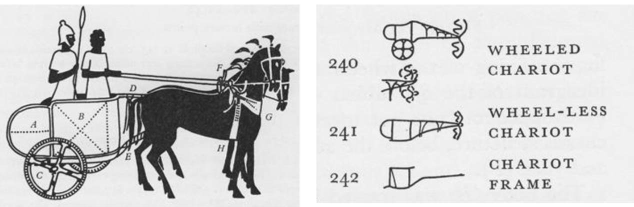

Figure 3. (left) Approximate appearance of a Mycenaean Chariot from Mycenaean vase-paintings, from the Tiryns fresco and from the analogy of contemporary Egyptian chariot harness and (right) Ideograms of chariots in Knossos tablets inscribed in Linear B ([[86], 269, Fig./Εικ. 18], [[34], 172, Fig. 13], [[78 version 1956], 361-362], [[28], 2:800-801 figs 18.2, 18.3.]).

Michel Lejeune, in a very detailed article ([94]), analyzed the matter of the chariots and wheels at Knossos (and Pylos). The tablets describe "complete" chariots with wheels (ideogram 240 in Figure 3-right - BIGA), chariot-frames without wheels (ideogram 241 in Figure 3-right - CURR) and chariot frames (ideogram 242 in Figure 3-right - CAPS). According to Homer, it was normal practice to remove the wheels from the chariot, when it was not in use, and to place it on stands and cover them by cloths.

According to Lejeune [94], the texts S of Knossos list two types of register: one register of distribution for the BIGA chariots and one register of the chariot's status for the CURR and CAPS chariots. Approximately 200-250 martial (war) chariots of the CURR type are described in the Knossos tablets and more than 300 of CAPS type, summing up -most likely- c.350 in total. The CAPS ideogram in the tablets is connected to production or repair works [[34], 169-170: with detailed bibliographic references].

Ruijgh [[95]] mentions that the ideogram 242 (CAPS) denotes that, in reality, the chariot was very much incomplete and perhaps ruined. The repair works, for the CAPS chariots, are justified also by a long list of shortages of the chariots in the tablets like reins or several different technical terms not easily understandable today. Moreover, the word in Linear B' 𐀕𐀲𐀐𐀓𐀕𐀙 = *me-ta-ke-ku-me-na* = *μετακεχυμένα* used for CAPS chariots from the verb *μετα-χέϝω* possibly means "*upheave*" (brouiller, bouleverser in French), leading probably to a "*smashed*" chariot. Schon [92] also refers to the word 𐀃𐀞 = *o-pa* of Linear B in Knossos Chariot Tablets and believes that most likely it designates refurbishment or finishing of the chariots. Ruijgh believes that [[95], 188]: "the chariot had been crushed/ruined/*tombé-en-débris* or had been dismantled, undoubtedly due to an accident" and on p.182 he speaks of a possible repair process. Driessen [[96], 486] believes that the CAPS logogram denotes incomplete or dismantled chariots and the Sf-series in the Armory (at Knossos) deal with incomplete chariot bodies. He also ([[96], 492-493] estimates a *ready to operate* Knossian chariot-force of 250 chariots and at least 500 horses. In p.485, Driessen refers that the Sd-series tablets are written by scribe (identified as) 128, an official also responsible for several other *military* related tablets. In p.487 Driessen sums up the CAPS chariot-frames ("ruined") in 150+ (+) 192+ = 342+, *more than 342*, 137% of the operating 250 chariots, which is a huge number.

The aforementioned documents are the only Linear B documents dealing with operational (and in depot) chariots. Summarizing the data, the Knossian chariot tablets record 200-250 chariots ready to operate and 300-350 chariots of "dismantled/ruined" type in depots for repairing or finishing works. The "dismantled" ideogram is connected to production or repair works or even of "chariot very much incomplete and perhaps ruined". Driessen, speaks for an "additional argument in favor of an oppressive, military inspired Mycenaean domination of Crete" and he concludes that, during the period around 1400BC, "it is not impossible that *some emergency situation existed at Mycenaean Knossos*, but as yet other corroborative evidence is lacking" [[96], 487].

All the above could lead to the implication that before the era of the destruction of Knossos (~1390-1370BC) a great number of chariots, possibly more than 350(+), were for repair at the workshops (while 250 were ready for operations), probably due to battles. For the date of destruction of Knossos the dating of Popham ([[98], 85: 1375BC]) is followed in this article, (see [[99], 44], [100], for references supporting that "the new generation of archaeologists, e.g. Hatzaki, accept Popham's date"; also [[101], 23: "new cultural elements across the island (of Crete) by LMIIIA2 signaled the transformation of 'Minoan' into 'Mycenaean' Crete", a quotation of [[102], 1031-1034], pointing to a change of dominance in the island).

The records for "dismantled chariots" could be a hint of the "emergency" described in Literature about Idomeneus and Leucus and, either after Idomeneus' victory he finally remained at Knossos, or -following the alternative version- after his defeat Idomeneus "was deported" and colonized Kalabria in southern Italy sometime between 1400-1390/1370BC according to the dating of the *Room of the Chariot Tablets*.

We could allegate also that the era between 1425-1390/1375BC is more compatible for a Trojan expedition from Crete and Knossos (under Idomeneus and Meriones), since at that era, Kydonia was a peripheral region attached to Knossos. This is in conformity to *Homer*, who does not mention Kydonia in the epics. The majority of the tablets found in Pylos -in this case- would be two hundred years later than the Fall of Troy, fact that could offer a logical explanation about genealogies in Homer and the inconsistencies between the epics and the information in Linear B tablets. As Malcolm Wiener mentions, the "genealogies in Homer run backward for a generation or two but never forward to a future dynasty" [[104], 21].

3.5 Deitiy-Horse, Deity-Ox, Deities-Animals

The great importance attributed at that time to the contribution of livestock to the economy is also emphasized by the fact that, probably, local deities are recorded: a "horse-deity" and other "deities-animals" (even a deity-reptile), which were preserved in some forms until the classical era [cf. [19], 270].

In Pylos (PY An1281), 𐀡 -]𐀴𐀛𐀊 𐀂𐀤𐀊 = *po-]ti-ni-ja i-qe-ja = Potniāi hikkweiāi = Πότνια (goddess) Ἱππεία̣ = goddess (h)Ippeia = goddess Horse* was read [[46], 2:462, 2:464], [[47], 2:878, 2:887], [[43], 2:963]], like Athena *Ἱππεία̣/(h)Ippeia* in the classical era [[59], 1:316-317], or like the horse-headed Demeter near Phygaleia in Arcadia[[47], 2:872]; [TLG-Paus.VIII, 42:1.1-2.1]] at the classical Peloponnese, [[78], 483], [[46], 2:464]].

The tablets that came to light in the Cadmeia of Thebes revealed a divine trinity consisting of three important deities: (a) the dominant figure was 𐀔 𐀏 = *ma-ka* = Μᾱ Γᾱ = *Mother Earth*, (b) followed by 𐀃 𐀡 𐀩 𐀂 = *o-po-re-i* = *ὀπόρει* = *fruit* dative singular of an adjective **ὀπόρης* namely "(Zeus) protector of fruits", and (c) the daughter of the two previous deities 𐀒 𐀷 = *ko-wa* = Κόρϝᾱ = *Kore* = *Maiden*.

Mother Earth would have been "the great deity of Mycenaean Thebes" and corresponded to the Demeter of the Eleusinian Mysteries of the first millennium BC too. An equally impressive revelation of these tablets is the existence of a cult addressed to a series of "sacred animals": 𐀓 𐀚 = *ku-ne*, and also *ku-no*, *ku-si* grammatical cases of the word *κύων (sing.) κύνες (plur.) = hound(s), dog(s)*, 𐀁 𐀖 𐀍 𐀜 𐀂 = *e-mi-jo-no-i* = *ἡμιόνοιhι* = *hemionoi(hi)* = *mules*, 𐀒 𐀫 = *ko-ro* = *χοίροι* = *pigs*, 𐀁 𐀟 𐀲 𐀂 = *e-pe-ta-i* = ἑρπεταί = *reptiles* (*snakes*), etc. The latter is compatible with Evans' finding at Knossos [[30], 138-145], which led him to conclude that it was a cult of domesticated snakes [see [35], 108-110]. All the animals (*living beings*) mentioned in this paragraph were closely associated with Demeter [[[25], 2], cf. [[47], 2:879, 2:889-890]].

Furthermore, in Mycenae (MY Oi701) there was the goddess 𐀯 𐀵 = *Σιτώ* = *Sito* (*Sītō*) = *goddess of wheat*, who evolved into the goddess Demeter [[[47], 2:879, 2:889-890], [[35], 104-107, 108-110: deities-animals, deities-reptiles]]. Rousioti [[65], 307-308]] reports that in Pylos (PY Fa16, PY Tn316) offerings were probably made to the deities 𐀂 𐀦 = *i-qo* = *ἵππος* = *horse* (cf. *Ποσειδών Ἵππος* or *Ἵππιος* = *Poseidon Hippos* or *Hippios* [[[106], 277-278: for *i-qi-jo god*], [[43], 2:963: uncertain taken by Palmer as god]] and 𐀦 𐀹 𐀊 = *qo-wi-ja* = *ᵍβο-ϝι-ια* = *ἀγελάδα* = *cow* (or "*she of the cow*" [[14], 95]) and in Mycenae (MY

FU711) *ku-ne* = *dog* and 𐀯 𐀸 = *qo-we* = *βοῦς* pronounced g^uō(n)s accusative plur., sing. g^uōn Βοῦς = ox; however, Rousioti [65] expresses serious reservations and disagreements regarding the validity of attributing the relevant Linear B texts to animal-gods. Of course, there are other opposing views too [[[47], 2:879, with bibliography], see also: [[82], 337], [[107], 302]]]: it is possible that, within the framework of a festive symposium -organized by the Palace- some of the participants were engaged in some kind of religious activity, which allowed them to participate in groups with animal names (dogs, mules, etc.) [[81], 232, note.106], or to dress in the skins of corresponding animals, e.g. bears in a bear hunting ritual [[85], 169]. It seems that in Crete, unlike Egypt, there were generally no deities in the form of animals [[107], 302]. Ultimately, "the iconography and archaeological finds from the Bronze Age Aegean do not support the argument that the above animals were treated as deities. However, it is difficult to deny that they played a role in the cult". I agree that, "it seems more likely that, here we are dealing with sacred animals, in an intermediate position between humans and gods, which were kept in places of worship that were under the control and financial support of the central administration" [[65], 311], namely the Palace.

4 Measurements of Draught Force, Work, Energy and Power of Livestock

The Linear B tablets do not record any measurements or even an estimate of the Power exerted and the corresponding Work and Energy by the horse and the ox.

For this reason, *we should go to the era of the first steam engines*, because the steam engines, after their invention, gradually began to replace the use of animals as sources of Work and Energy. *The first steam engines therefore inevitably had to be compared in terms of their performance with the Work and Energy provided by livestock*. The steam engine was invented in 1698AD by the Englishman Thomas Savery [70] and in 1712 by Thomas Newcomen [8], and was improved in 1765 by the Scottish (Civil) Engineer James Watt, who drastically reduced steam losses and fuel consumption and patented [[10], [8], [9]] this invention on January 5, 1769 ([[1], xiv, 32-42: description of the steam engine of J. Watt]). At the end of the 18th century AD, J. Watt named the unit of power as *horsepower* (*hp*), to compare the output of a steam engine (this unit is also used today for other mechanical equipment such as piston engines, gas turbines, electric motors, etc.) with the power of a strong horse pulling a cart, and usually this unit is 50% greater than the output of an average horse during a working day [9].

However, a question arises: *how efficient were the horses during the Mycenaean era compared to the horses in the 18th century AD*?

Robert Caro [[[12], 502-515], [[57], 87]] gives us a brilliant Hesiodian depiction of the physical and spiritual hardships of life in the Texas mountains between 1850-1940AD. Palaima [[57], 85-89] refers to Caro and the use of cattle in America in the mid-19th century AD and ascertains that, *since Mycenaean era, their use must not have changed*; *the attitude and behavior of people towards them is not much different*: people used cattle and received the produced Work and the products derived from them (milk, cheese, meat, leather, animal glue, etc.).

Therefore, it is logical to examine Watt's experiments after which the unit of Power was determined under the name *Horsepower* (*hp*). Next, it should be examined whether any Universities or official Organizations have dealt with the issue of the performance of other animals, and especially cattle.

In 1782, Watt experimentally determined that a "brewery horse", that is, a horse that provided its power in the production of beer by turning around the brewery-mill, according to Watt's calculations based on data he had, a mill horse made 2,5 revolutions per minute and covered a circular road 24 ft in diameter; he assumed that this horse exerted a pull of 180 lbs -without knowing where he got this number from- and was led [[21], 145] to believe that it produced 32.400 foot·pounds/min (i.e., ft·lbs/min) and rounded it to 33.000 ft·lbs/min the following year [[[48], 171-172], [73]]; for the physical explanation see Fig. 4.

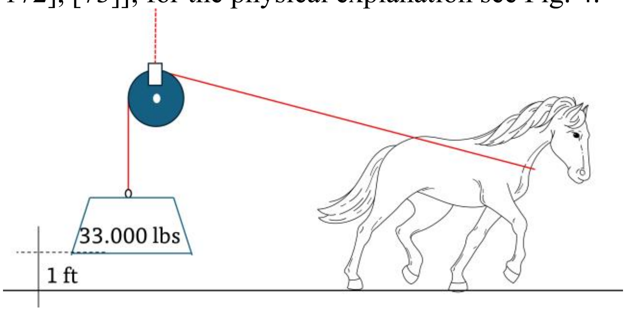

Figure 4. The Energy corresponding to a Horsepower (1 hp) per unit of time (sec) is equal to 33.000 lbs lifted to a height of 1 ft.

Watt calculated that a horse turned a mill 144 times an hour [[40], 118-**121**]. There are many systems of units: today in the British Imperial System, Horsepower, 1hp = 33.000 ft·lbs/min = 550 ft·lbs/sec = 2.545 BTU/h (British Thermal Units) = 745,7 watts (International System of Units [SI]) ≈

≈0,75kW. We record here the equivalences among different units: 1 ft = 0,3048m; 1 lb = 0,4536 kg; 1 kg-force = 2,205 lbs; 1 min. = 60 sec.; 1 BTU = 779 ft·lbs = $2,930x10^{-4}$ kW·h; 1 BTU/h = 0,2161 ft·lbs/sec = $3,919x10^{-4}$ hp; 1 hp = 2.545 BTU/h = 0,7457 kW = 745,7 W [[37], A2-A8]. 1 lb·ft = (0,45359237 kg) · (9.80665 N/kg) = 4.4482216152605 N (Newton).

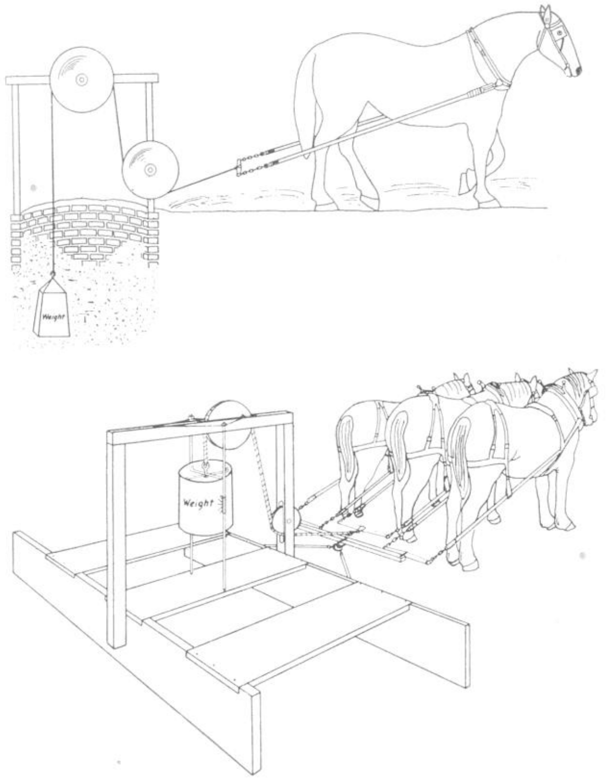

Figure 5. (Upper illustration) First experimental setup used for testing with a draft horse by Iowa University. (Lower illustration) Simple method used to apply a defined, uniform load to the horse at the center (of the three) [[16], 197].

In 1926, the University of Iowa, USA, published the results of a series of experiments that lasted over two years on the Power of horses (Figs 5), after which it emerged that [[[16], 233], see also, [73]]:

- ✓ "Two years of work have clearly shown that it is possible for horses weighing from 1.500 to 1.900 lbs -or more- to continuously pull loads of 1 horsepower (hp) -or more- and for periods "*longer than one day*". The work in the summer of 1923 covered 154 consecutive days and the 1924 experiment covered 219 consecutive days, including Sundays and holidays.
- ✓ "A well-trained horse can withstand an overload of over 1,000% for a short period of time. No other type of mechanism/machine can withstand such overload".
- ✓ "A pair of horses (cf. Mycenaean ZE in Linear B) developed a (maximum) Power reaching 29.76 hp in an official test".

San José State University, California, USA, and Thayler Watkins ([80]) have uploded the following *Table 1* with comparative performances of various living beings:

Table 1: Power of living beings

Living Being	**Draught Force** (lbs)	**Speed** (ft/sec)	**Power** (ft·lbs/sec)	**Horse-power** (hp)	**Comparison of Power** (%)
Horse	120	3,6	432	0,864	100
Ox	120	2,4	288	0,576	66,67
Mule	60	3,6	216	0,432	50
Donkey	30	3,6	108	0,216	25
Man	18	2,5	45	0,090	10,42

In *Table 1*, the Power of a Horse is less than the Iowa experiments, which were conducted much closer to the time when horses were the main source of Power and Energy for humans, therefore they attracted more attention and care and were used to "heavy work". However, *Table 1* is a useful guide for comparing performances between horses and oxen, as well as other living beings.

The above discrepancies led me to investigate other sources that report measurements and comparisons of the Power of living beings, the man was included also.

Man develops a total power of 0,5 hp from the food he eats. However, only 0,1 hp is available for useful work. The remainder is expended on bodily functions (basal metabolism). This norm is based on an adequately fed 35-year-old male European laborer working an 8 hours (h) day and a 48h week. A man of 20 can generate approximately 15% more useful energy than the norm, and a 60-year-old about 20% less. Based on the above norm, an equation for useful power for work lasting from 4 min to 8 h can be expressed by the equation (*as given in* [[3], 9-4/9-5]:

$$hp = 0.35 - 0.09 \log t \qquad (1)$$

where t is in minutes, for a 35 years old man [[[11], 7], [[49], 9-4/9-5, 828-829]], the diagram of Eqn (1) is depicted in Fig.6.

Table 2: Developed Power by a Man in a working period of 4min - 8h, [[11], 7]

Work Period	**4m**	**15m**	**30m**	**60m 1h**	**120m 2h**	**240m 4h**	**360m 6h**	**480m 8h**
Power (hp)	0,29	0,24	0,21	0,19	0,16	0,13	0,11	0,10

where, m (e.g., 30m) means minutes and h (e.g., 8h) means hours.

The equation predicts that a man can provide work at the rate of nearly 0,3 hp for 4 min, but at only 0,1 hp over 8h. A man's muscles also provide an overload energy capability of approximately 0,6 hp·min. For bursts of energy for less than one second, up to 6 hp may be expected.

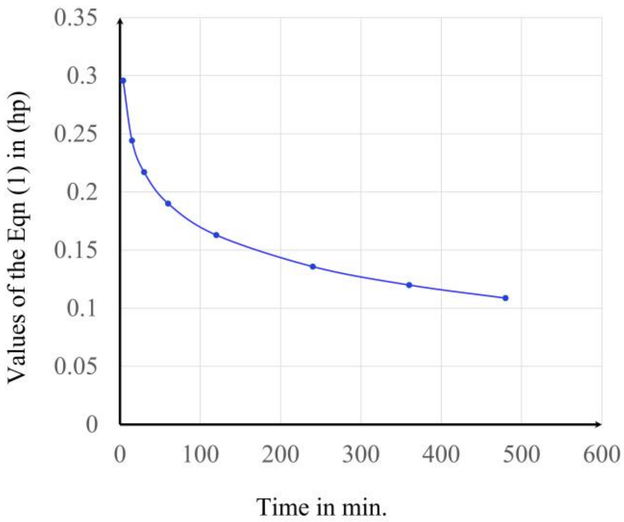

Figure 6. The diagram of Eqn (1) for useful Power in (hp) for work lasting from 4 min to 8 h based on an adequately fed 35-year-old male European laborer.

Neither high draft (force) nor high speed by itself indicates high power output. Power is the product of draft (force) and speed. The following equations are valid [[11], 11]:

$$hp = \frac{draft(lb) \cdot speed(mph)}{375(lb \cdot mph)} \Rightarrow$$

$$\Rightarrow draft(lb) = \frac{375 \cdot hp[lb \cdot ft]}{speed[mph]} \qquad \text{Eqns (2)}$$

$$hp_{metric} = \frac{draft(kg\_force) \cdot speed(km/h)}{270(kg\_force \cdot km/h)} \Rightarrow$$

$$\Rightarrow draft(kg\_force) = \frac{270 \cdot hp_{metric}}{speed(km/h)}$$

Animals can, over a short period of time, develop much higher power than that produced during normal work. For example, a good pair of draft horses can develop 20-25 hp for 10 sec, while a yoke of good oxen can generate 20-30 hp over a distance of 100 m. When harnessing animals of equal strength together, the draft of the individual should be multiplied by 1,9 for two animals, 2,5 for three, 3,1 for four, 3,5 for five, and 3,8 for six. For example: if one ox can provide a draft of 600 N, then a yoke of 2 oxen can provide 1.9 x 600 N or 1140 N. If 6 oxen are yoked together, the draft is 2280 N -only double that of 2 oxen. Animals of the same breed, age, fitness, and training should be used in a team. Otherwise, the weak or ill-trained individual will reduce the team's output [[11], 12].

Table 3: Draft and Horsepower [[[11], 11], [[31], 10-11]

Being	Average Weight (kg)	Approxim. Draft kg-force (lb)	Average Speed (km/h)	Horsepower Developed (hp, %)
Bullock	500-900	60-80 (130-175)	2,00-3,00	75
Cow	400-600	50-60 (110-130)	2,50	45
Water Buffalo	400-900	50-80 (110-175)	2,90-3,20	75
Light Horse	400-700	60-80 (130-175)	3,60	100
Mule	350-500	50-60 (110-130)	3,20-3,60	70
Donkey	200-300	30-40 (65-90)	2,50	35
Camel*	450-500	40-50 (90-110)	4,00	67
Man	60-90	30 (65)	1,00	10
* [[84], 321-322]				

Campbell ([11]) quotes measurements performed by the Food Agriculture Organization (FAO from now on, see [[31], [32]]) of the United Nations. *Table 3* above, provides the magnitudes of approximate Draft Force and the developed Horsepower by various animals: Bullock, Cow, Water Buffalo, Light Horse, Mule, Donkey and Camel compared to the Man, after measurements of FAO [[31], 10-11). *Table 4*, below, presents Normal Draught Power for Arid and Tropical Regions, according to FAO ([[31], 10, Table 2).

Table 4: Normal Draught Power for Arid and Tropical Regions ([[31], 10, Table 2).

Animal	Average Weight (kg)	Approxim. Draught (kg-force)	Average Speed (m/sec)	Power Developed (kgm/sec)	(hp)
Light Horses	400-700	60-80	1,00	75	1,00
Bullocks	500-900	60-80	0,60-0,85	56	0,75
Buffaloes	400-900	50-80	0,80-0,90	55	0,75
Cows	400-600	50-60	0,70	35	0,45
Mules	350-500	50-60	0,90-1,00	52	0,70
Donkeys	200-300	30-40	0,70	25	0,35

Table 5: Results of Drawbar Tests with Various Animals [[31], 10, Table 3].

Animals	**Maximum Drawbar pull expressed in kg**	
	Two Hours of Work	**Four Hours of Work**
	kg	
Heavy Horses	260-290	240-270
Light Horses	180	160
Mountain Oxen (Draught Cows)	160-170	140-150
Oxen from the Plains (Draught Cows)	140-150	120

Table 6: Draught Requirements of Some Farm Implements for Operations on Medium Loam Soils [[31], 11, Table 4]

Operation	Requirement (kg)
Ploughing Fallow Land with single Mouldboard	89
-11,40cm wide, 12,70cm deep	
-14,00cm wide, 12,70cm deep	94
-16,50cm wide, 15,20cm deep	121
-25,00cm wide, 12,70cm deep	170
Ploughing Fallow Land with double Mouldboard	116
-30,00cm wide, 5,50cm deep	
Harrowing Ploughed Soil	
-18-tine peg tooth harrow, 6,30cm deep	46
-5 spring tines, 11,40cm deep	118
-Heavy Harrowing 165-320cm wide	80-100
-Light Harrowing 320cm wide	90
Levelling Ploughed Soil with a 180cm long board ridden by a 53kg person	90
Rolling	96
Cultivating, 3-tine cultivator, 9,00cm deep	53
Seed Drilling, 175-200cm wide, 11-13 openers	90
Wheeled Transport of Loads up to 1 metric ton on average farm roads	90-120

Campbell quotes [32] of FAO for these values, since it was published after measurements performed by the Food and Agriculture Organization of the United Nations. This work gives Tables 4, 5, 6. The results of each animal are dependent on the quality of the soils too. Thus, *Table 6* provides the Draught Requirements of Some Farm Implements for Operations on Medium Loam Soils.

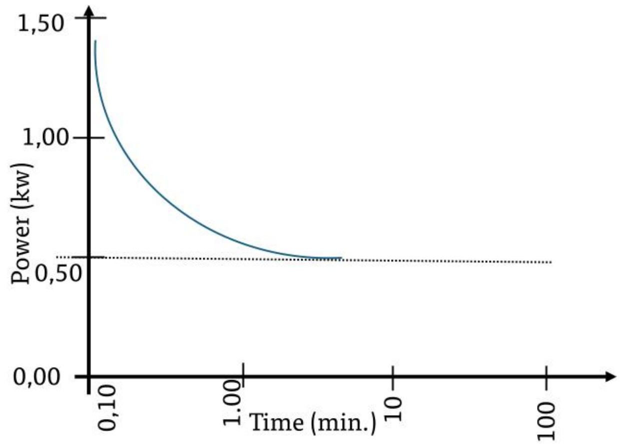

Figure 7. Maximum power *vs* maxi-mum time characteristics for humans (*out of scale*) [[54], Fig. 1], after, [[83], Fig. 2, Fig. 1].

As far as human beings is concerned, for a short period of time very heavy work can be performed, but the total Power output diminishes steeply the longer the total duration of exercise. However, when the duration of work is greater than about 5 min, the rate of work efficiency diminishes with increasing duration of exercise, as Fig. 7 shows depicting the Maximum Power *vs* Maximum Time characteristics for humans ([[54], Fig. 1], after, [[83], Fig. 2, Fig. 1], *see also* [60]); the graph in Fig. 7 is in accordance with the Equation (1) above and its depiction in Fig. 6. For the *Maximum Forces* exerted by living beings in several activities see [2].

5 Discussion

The error in using a time-averaged force (taken over short time periods) for calculation of work done (by oxen) has been illustrated by Lawrence/Pearson [[52], 709-714]; this is valid for all living creatures too. Relevant results of measurements in draught animals are presented in FAO-RECTMAE [[32], 29-31, 226-and-after]. The maximum forces exerted by animals is a percentage of their body weight.

The energy efficiency of animals is the subject of considerable disagreement. The Food and Agriculture Organization [32] states that the energy efficiency is 9-10% for bovines and 10-12% for the horse family. P.S. Rose [[64], 217-219], on the other hand, states that the horse has an efficiency of about 20% and man 19.6% [cf. [[11], 10]]. Thyler Watkins (Table 1, above) also gives slightly(?) different values. "*The difference among these authorities and researches is probably due to the means by which work is obtained from the animal, whether by draft or by a treadmill*" [[11], 10].

6 Synopsis - Conclusion

The article examined records of livestock in Linear B tablets; the livestock was used as Energy and Power source(s) in Agriculture, Transport and other activities. The tablets record oxen 𐀸 𐀏 𐀲 = *we-ka-ta* = *ϝεργᾱται* = *workers*" (which, apparently, were used in agricultural work in PAIRS), horse-drawn chariots with the harness of the horses that pulled them, etc.

The great importance attributed to the contribution of livestock to the economy is also emphasized by the fact that the chariot in Linear B is called "𐀂 𐀣 𐀊 = *i-qi-ja* = *ἰππία*", that is, "drawn by a horse" since the term vehicle was omitted.

The Linear B tablets do not record any measurements or even an estimate of the Power exerted and the corresponding Work and Energy by the horse and the ox.

For this reason, we should go to the era of the first steam engines, because the steam engines, after their invention, gradually began to replace the use of animals as sources of Work and Energy. The first steam engines therefore inevitably had to be compared in terms of their performance with the Work and Energy provided by livestock. This is the closest approach to the livestock of the Mycenaean era -as sources of Energy and Power.

Today the unit of measurement for Power is called *horsepower* (*hp*), *a reference to the great importance attributed to the horse throughout the centuries*. Animal Power measurements were initially determined by the experiments of James Watt in 1782-1786 AD; later research was performed by Universities and Organizations of the 19th until 21st centuries AD and the results were presented in this article.

Acknowledgement:
I want to specially thank professor T.P. Tassios for his suggestions which led me to search for James Watt's experiments and, also, for the experiments and their results presented in Tables 2-6. By all means, the existing mistakes are exclusively mine.

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ANNEX A: Syllabograms of Linear B script