Noria al-Muhammadiyya

Historic Mechanical Engineering Landmark

ASME

The American Society of Mechanical Engineers

Hama, Syria

December 2006

“This large blessed noria was built in order to take water to the al-A’la mosque during the life of our Honored and Respected Lord, guarantor of the Hamath Kingdom in the year 763.”

An inscription on the eastern face of the column of the thirteenth arcade of the Noria Al-Muhammadiyya.

The inscription specifies that this noria was built by Aydamar Ibn ‘Abd Allah al-Sayhi al-Turki in the year 763 of the Hijri Calendar (1361 CE).

The founder was twice governor and represented the Ottoman Empire in Hama, first of Shawwal 762 AH to Sha’ban 769 AH (1360-1368 CE), then from Shawwal of 769 AH until his death in 773 AH (1368-1371 CE). He was buried in the tomb that he had built for himself in Hama.

In addition to supplying water to the Grand Mosque, this noria provided water to the public bath of Hammam al-Dahab, to the gardens around the mosque, and to the houses and the fountains of the same quarters or neighborhood.

The Islamic calendar (or Hijri calendar) is a purely lunar calendar. It contains 12 months that are based on the motion of the moon. Years are counted since the Hijra, that is, Mohammed's emigration to Medina in 622 CE. On 16 July (Julian calendar) of that year, AH 1 started (AH = Anno Hegirae = year of the Hijra)

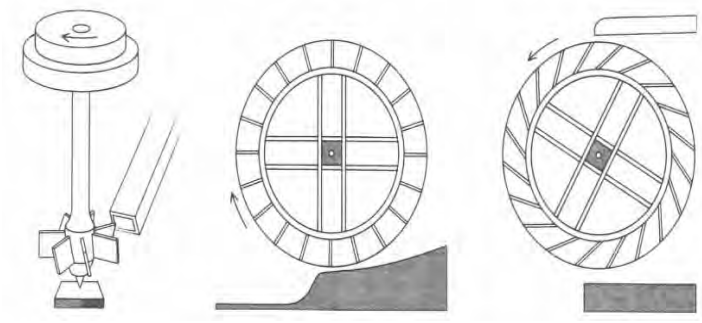
Harvesting of Energy

For thousands of years prior to the industrial revolution, the water wheel was the sole technology enabling humanity to harness large amounts of energy. The earliest known reference to water wheels dates to about 400 BCE.

Water-driven wheels were used for a variety of purposes such as water lifting, grinding and metal-working. One of the earliest versions of water wheels was a small vertical-shaft wheel used mainly to grind wheat. This version was basically a millstone mounted atop a vertical shaft with a vaned or paddled wheel at the lower end. When the wheel was immersed in a river or a swift stream, the energy of the flowing water turned the millstone, which was then used to grind wheat.

Vertical shaft wheels were limited in the amount of power they could deliver and were not useful for lifting water. In later versions, a horizontal shaft was used instead. The vertical wheel attached to it had radial vanes, paddles or buckets around its edge. The buckets filled with water during the down-travel part of the cycle, retained the water during most of the up-travel part of the cycle, and completely emptied near the top. A water tank next to the water wheel collected the water as it poured out of the buckets near the top. A network of water channels then distributed the water to irrigate farms or to provide drinking water to cities.

Both vertical and horizontal shaft water wheels are believed to have originated in the hilly regions east of the Mediterranean where the fast-running River Orontes flows. The work of these ancient engineers developed the fundamental technology which served as the foundation necessary to support and extend these sophisticated societies in this area.



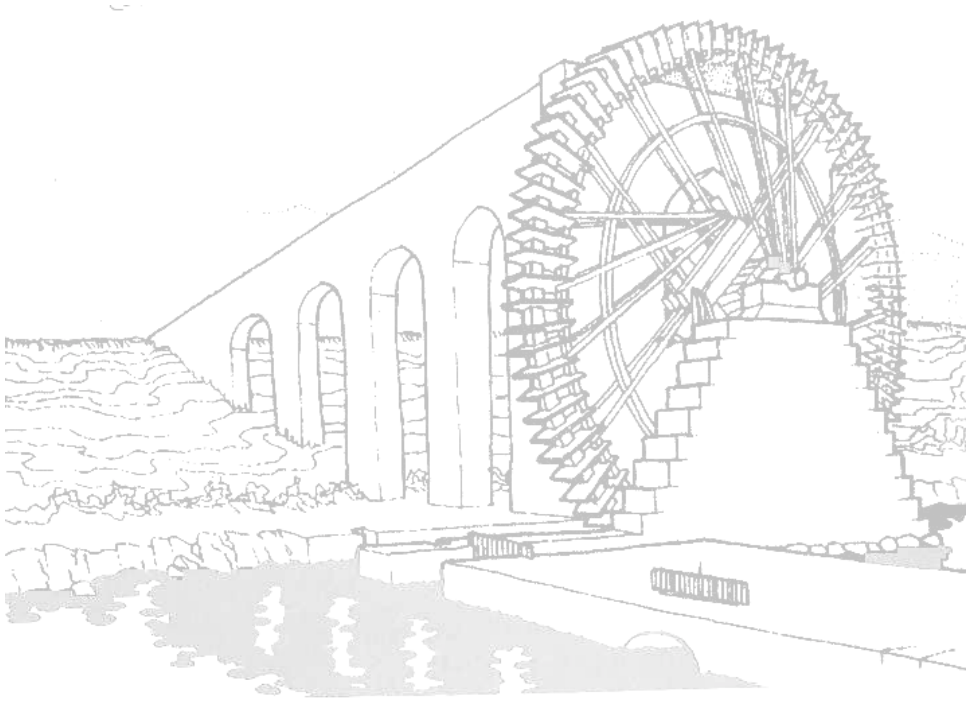
Vertical and horizontal shaft water wheels
(Drawing from Scientific American)

The more advanced horizontal-shaft wheel dates to about 200 BCE. The design of horizontal-shaft water wheels evolved over the centuries and became mastered by the engineers of ancient Syria. A design advocated by Vitruvius around 27 BCE suggests that the Romans took this invention to Europe sometime in the first century BCE. *(Derry and Williams, 1993)*. In medieval times, the number of water wheels in Europe skyrocketed In 1085 CE, for example, the *Domesday Book* reported that 5,624 wheels were in use in England south of the River Trent. Based on this count, the number of water wheels in Europe at that time must have numbered in the tens of thousands.

The water wheel retained immense industrial importance long after the invention of the steam engine. From the sixteenth until well into the nineteenth century, water wheels were the most important sources of power in Europe and North America. For example, London pumped its water supply from the river using water wheels until as recently as 1822. *(Derry and Williams, 1993)* In the U.S. as late as 1870, water wheels and water turbines still provided more power to factories than did steam engines. Indeed, the Industrial Revolution led to considerable improvement and utilization of water wheels before steam engines eventually rendered them obsolete.

The viability of water wheels as a power source was always constrained by key environmental factors. Thus, water wheels were rarely used in areas with slow-running rivers such as found in Egypt and Mesopotamia.

The word noria is an English word meaning a device for raising water. Noria finds its origin in the Arabic word "naurah." This word is used in Syria for a water wheel* and literally means "the wailer." The name refers to the wailing sound made during operation that is created by its wooden bearings. The sound is a mixture of noise and true musical notes that is often compared to organ music. The deepest notes are in the range of 120 - 170 Hz.



NOTE: All norias are water wheels but not all water wheels are norias. A water wheel typically drives something else e.g. a grindstone, machinery etc. A noria raises water from a stream or river and discharges it at a higher elevation.

Hama - The City of Water Wheels

Of the tens of thousands of water wheels that were built around the world, very few have survived. In the city of Hama, however, a set of seventeen large water wheels continues to operate on the River Orontes as they have for many centuries.

These norias irrigate farmland as well as supply drinking water to communities lying next to rivers. Their purpose distinguishes them from other versions of the water wheel that supplied power for wheat-mills, sawmills, fulling-mills, ore-crushing plants, hammer mills for metal working, mills to operate the bellows of furnaces, and other applications.

The following is a recent account of these water wheels: *(Delpech et al., 1997)*

Noria al-Bisriyya: This noria, which was initially called al-Hagibiyya, has two wheels with different diameters. The larger diameter is approximately 18 m (59 feet). Its tower was completely rebuilt by the Hajj Muhammad al-Haris, a master mason from Hama. Its most recent restorations date from 1977 and 1988.

Noria al-Utmaniyyatani: Located on the same dam causeway as the Noria al-Bisriyya, it also has two twin wheels. This group of four wheels constitutes the famous group known as the "Four Norias." In the mid-20th century, the aqueduct of this noria was almost completely rebuilt with wooden frames. These two wheels, constantly maintained and repaired, are now in working order.

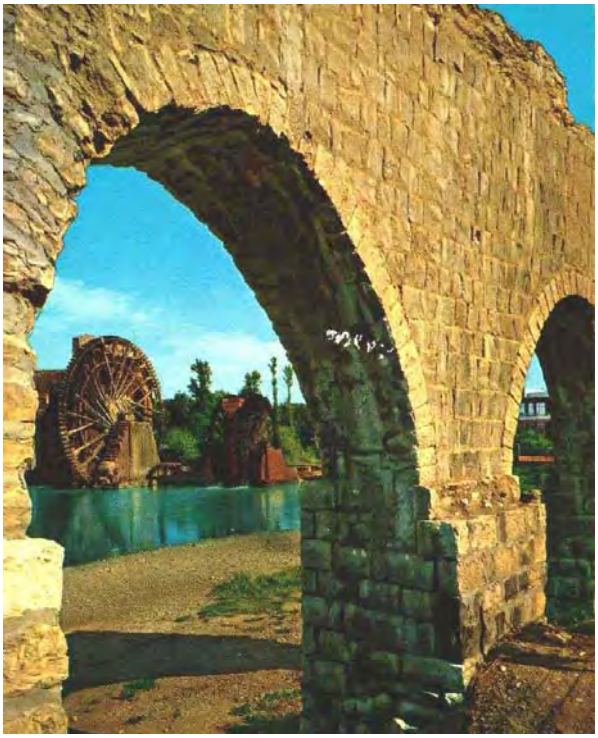
Noria al-Gisryya: This noria was first called al-Yazbakiyya, then al-'Ubaysi. A long portion of this aqueduct still exists, especially in the Umm al-Hasan public garden.

Noria al-Ma'muriyya: This was the second largest noria on the River Orontes after Muhammadiyya. After the latest renovation, its wheel diameter was 21 m (69 feet). On the southern part of its tower is an inscription indicating that the foundation of this noria was built by Prince Balbak in 857 H. (1453 CE).

Noria al-'Utmaniyya: Located near the preceding one, this noria is of medium size. Its wheel has a diameter of 11 m (36 feet). It was completely restored in 1980.

Noria al-Ma'ayyadiyya: Previously called the Noria al-Hanqah, it is located at the same place as the two preceding ones; this group of three norias was associated with a mill, which took advantage of the deviation of the current at this point on the left bank of the river. Its wheel and the tower of its aqueduct were rebuilt in 1979, but the aqueduct was not restored. With a diameter of 7 m (23 feet), this is one of the smallest existing norias on the River Orontes.

Noria al-Ga'bariyya: This noria is part of a group of three located on both sides of the same dam built on the river, upstream of the al-'Azm Palace. It was restored in 1981 and 1983. On September 1, 1988, its aqueduct collapsed, leading to the destruction of the wheel. All was rebuilt right away. The wheel has a diameter of 17 m (56 feet).



Noria al-Sihyuniyya: Together with the preceding one, at the same end of the dam, this is a single wheel noria of medium diameter of about 10 m (33 feet). It was rebuilt in 1981 and restored in 1988.

Noria al-Kilaniyya: This noria was built against the facade of the Kilani palace, which no longer exists. Its wheel is approximately 12 m (39 feet) in diameter. It was restored in 1981, and again in 1988.

Noria al-Hudura: Located north of the citadel of Hama, together with the next two, it was part of a group of three norias installed at the ends of the same dam. This noria was restored in 1982, 1983 and 1988. Its wheel has a diameter of 17.5 m (57 feet).

Noria al-Dawalik: The aqueduct of this noria has completely disappeared, but its wheel was restored in 1983 and 1988. On the left bank, it and the preceding one operate a mill.

Noria al-Dahsa: This noria is located across from the preceding two norias, with which it shares a dam. Its wheel is small but has several peculiarities: it does not have an inner circle; its buckets are alternately large and small; and its "triangle" is rectangular in elevation. It was restored in 1988.

Noria al-Muhammadiyya: The subject of this landmark designation, this noria is more fully described elsewhere in this brochure.

Noria al-Maqsaf: This is one of the smallest norias on the River Orontes, and shares a common dam with the preceding one, which is larger. This group also contains a mill. It was restored in 1984.

The water wheels of Hama are often cited as major works of art and treasured remains of an ancient civilization. Today, most of the surviving water wheels in Hama are in good structural condition. They continue to be operated, primarily for tourism purposes. Because of their uniqueness, they stand as one of the major tourist attractions of the Middle East that have been visited by millions of tourists.

Noria al-Muhammadiyya

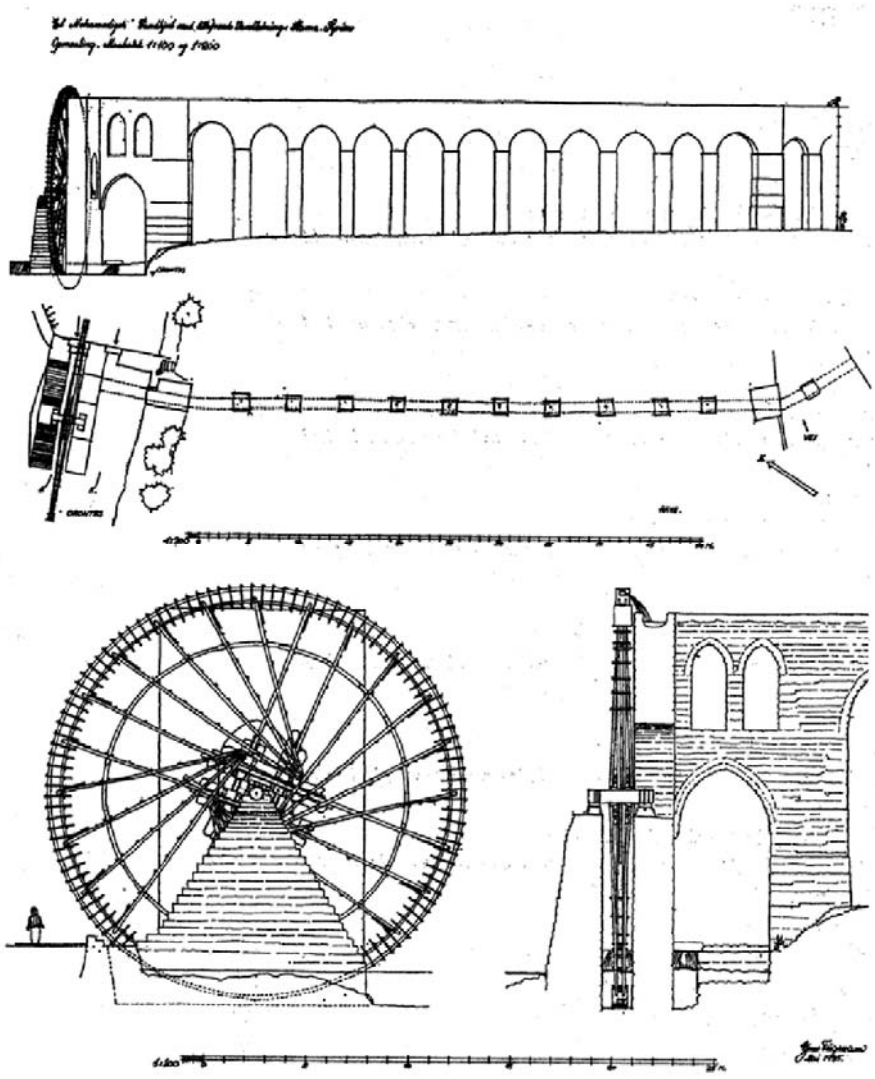
The subject of this landmark is the most famous of the many norias in Hama. This giant operating noria is unique in both size and age. It is located downstream from Hama, Syria in a place called Bab al-Nahr (the gate of the river).

The diameter of its wheel is 21 meters (69 feet). Fourteen of the arches of its aqueduct still exist. Compared to the typical known size of water wheels of 2 to 3 meters (7 to 9 feet), the Noria al-Muhammadiyya is among the largest water wheels ever constructed. It was restored in 1977 and is currently in service.

The Noria al-Muhammadiyya was built in 763 AH (1361 CE), probably at the site of much older water wheels. While other water wheels in Hama may be equally old, their age cannot be verified.

The Noria al-Muhammadiyya raises water from the River Orontes to an elevated aqueduct. The water is then distributed to the al-A'la Mosque, the public bath of Hammam al-Dahab, the gardens around the mosque, and to the houses and fountains of the neighborhood.

The sketch below is the oldest available scale drawing of this water wheel. It was made by the Danish architect Einar Fugmann in 1935 (Schioler, 1973).



Mechanical Features

The norias of Hama are stand-alone water pumps. The river that provides the water they raise also serves as their sole source of energy. A comprehensive description of the mechanical features of Hama's norias is found in *(Delpech et al., 1997)* which is the source of most of the information in this section.

The operation of the noria is simple: The current of the River Orontes pushes against the paddles on the rim of the water wheel, causing it to rotate. Compartments or buckets attached to the wheel fill with water as they pass through their bottom position in the river and are emptied into an elevated aqueduct as the wheel lifts the buckets to their top position. These buckets range in volume between 4 and 12 liters (1 to 3 U.S. Gallons)

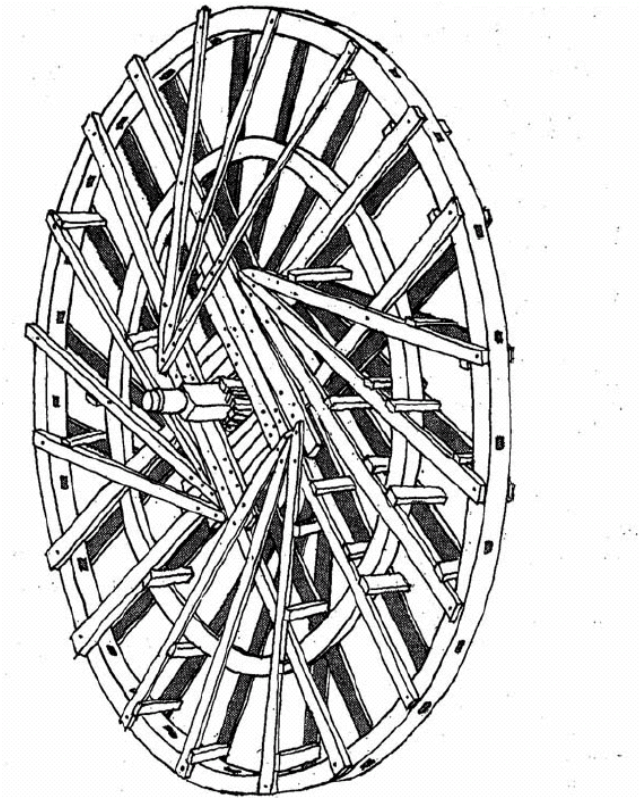
A not to-scale structural detail of a typical wheel (outer rim removed for clarity) is shown in the sketch below. A typical segment of the rim that includes two paddles and a bucket is also shown. *(Schioler, 1973)*

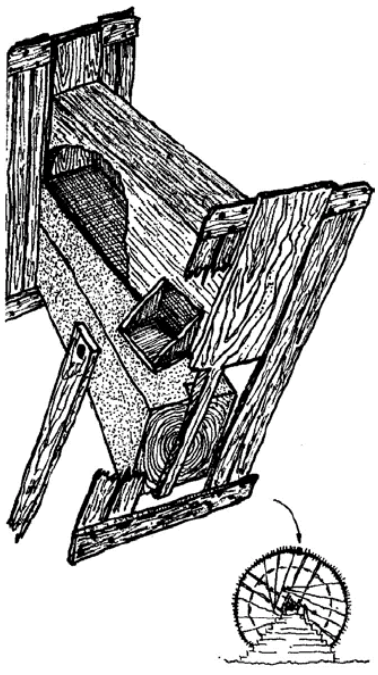
Norias are typically made of several types of lumber. The selection for each component is primarily a function of the stresses to which it is exposed during operation and maintenance.

The shafts and bearings are typically made of hard walnut tree wood. Friction between the two lumber components is initially high and creates loud unsteady noise. After a short period of water-cooled operation, surfaces smooth out and friction becomes minimal.

The weight of a recent replacement of a 12 m twin-type noria was estimated at 4,200 kg (9,260 pounds) consisting of 4,000 kg (8820 pounds) of lumber and 200 kg (441 pounds) of nails.

According to measurements taken in 1987 and 1990, norias take between 12 and 56 seconds to complete a full rotation in low season and deliver between 50 and 200 m^3 (13,200 to 52,800 U.S. Gallons) of water per hour. The Noria Al-Muhammadiyyah is right at the high end of both ranges.





Future Outlook

Most of the surviving water wheels in Hama are currently in good condition and continue to be operated primarily for tourism purposes. However, due to increased water demands from the River Orontes caused by population growth, river water flow is rapidly decreasing. This reduction in flow has made the water wheels of Hama inoperable for extended periods each year. When not immersed in water for lengthy periods of time, these wooden water wheels tend to shrink and crack, making it much more difficult to preserve or operate them.

The historical value of these surviving engineering treasures cannot be overstated. The preservation and maintenance of the water wheels is conducted and financed primarily by the local community in Hama. This recognition by ASME International serves to underscore the significance of these monuments. Perhaps this designation will also encourage international funding to aid the preservation of this unique technological heritage for future generations.

Acknowledgments

The South Texas Section of the American Society of Mechanical Engineers International acknowledges the efforts of those who contributed to the designation of the Noria Al-Muhammadiyya as an ASME International Historic Mechanical Engineering Landmark.

Dr. Mahmod Samman, P.E. submitted the nomination and is the brochure's principal author and translator. Mark W. Powell, P.E. led the effort to plan the ceremony and edit this brochure. Special thanks to ASME officers Dirk F. Dauw and Hasan Sabri for their support and to local members Samer Maatouk and Zaki Haddad for helping to organize the ceremony.

For Further Reading

Delpech, A., Girard, F., Robine, G., and Roumi, M., 1997, *Les Noria De L'Oronte*, Institut Francais De Damas, Damas. (Translated from French by Michael B. Michaud of ASME)

Derry, T. K., and Williams, T. I., 1993, *A short history of technology from the earliest times to 1900*, Dover.

Schioler, T., 1971, *Roman and Islamic Water-Lifting Wheels*, Odense University Press, Denmark.

Usher, A. P., 1982, *A History of Mechanical Inventions*, Revised Edition, Dover.

The History and Heritage Program of ASME

The History and Heritage Landmarks Program of ASME (the American Society of Mechanical Engineers) began in 1971. To implement and achieve its goals, ASME formed a History and Heritage Committee initially composed of mechanical engineers, historians of technology and the curator of mechanical engineering at the Smithsonian Institution, Washington, D.C. The History and Heritage Committee provides a public service by examining, noting, recording and acknowledging mechanical engineering achievements of particular significance. This Committee is part of ASME's Center for Public Awareness. For further information, please contact Public Awareness at ASME, Three Park Avenue, New York, NY 10016-5990, 1-212-591-8614.

Designation

Since the History and Heritage Program began in 1971, 242 landmarks have been designated as historic mechanical engineering landmarks, heritage collections or heritage sites. Each represents a progressive step in the evolution of mechanical engineering and its significance to society in general. Site designations note an event or development of clear historic importance to mechanical engineers. Collections mark the contributions of a number of objects with special significance to the historical development of mechanical engineering.

The Landmarks Program illuminates our technological heritage and encourages the preservation of the physical remains of historically important works. It provides an annotated roster for engineers, students, educators, historians and travelers. It helps establish persistent reminders of where we have been and where we are going along the divergent paths of discovery.

The 120,000-member ASME is a worldwide engineering society focused on technical, educational and research issues. ASME conducts one of the world's largest publishing operations, holds some 30 technical conferences and 200 professional development courses each year, and sets many industrial and manufacturing standards.

ASME

Terry E. Shoup, PE, President
Walt Laity, Senior Vice President
Virgil R. Carter, FAIA, Executive Director

ASME History and Heritage Committee

J. Lawrence Lee, P.E., History and Heritage Chair
Robert Casey
Robert Friedel
R. Michael Hunt, P.E., Immediate Past Chair
Richard I. Pawliger, P.E.
Mark Powell
Paul J. Torpey, Past President
Herman Viegas, P.E.
Marina Stenos, Manager, Public Awareness
Wil Haywood, Communications Coordinator

ASME South Texas Section (nominator)

Ryan Schmidt, Chairman
John Bradford, Vice Chairman
Greg Berry, Treasurer
Robert Bradshaw, Secretary

City of Hama, Syria

Mohamad Ameen Kendacji, Mayor

LANDMARK DEDICATION CEREMONY

Hama, Syria
December 21, 2006

Hosted By:
The Honorable Mohamad Ameen Kendacji, Mayor of Hama
Dr. Mahmod Samman, Landmark nominator
Adrienne B. Nutzman, Cultural Affairs Council attaché, US Embassy in Damascus
Abdel-Razzak Al-Asfar, waterwheel researcher and author
Samer Maatouk, local ASME representative


TINUE TO OPERATE
RIA ARE UNIQUE
AL-MUHAMMADIYYA
A DIAMETER OF 21
LARGEST WATER
RY EXISTE
ENGI

HISTORIC MECHANICAL ENGINEERING LANDMARK

NORIA AL-MUHAMMADIYYA

763 AH (1361 CE)

FOR THOUSANDS OF YEARS PRIOR TO THE INDUSTRIAL REVOLUTION, THE WATER WHEEL WAS MANKIND'S ONLY MEANS OF HARVESTING AND UTILIZING LARGE QUANTITIES OF ENERGY. IMPORTANT IN THEIR OWN RIGHT, THESE ANCIENT DEVICES ALSO PAVED THE WAY FOR WATER MILLS, WINDMILLS, AND MODERN TURBINES.

THE GIANT WATER WHEELS THAT CONTINUE TO OPERATE ON THE RIVER ORONTES IN HAMA, SYRIA ARE UNIQUE IN BOTH SIZE AND AGE. THE NORIA AL-MUHAMMADIYYA DATES TO 763 AH (1361 CE). WITH A DIAMETER OF 21 METERS (69 FEET), IT IS AMONG THE LARGEST WATER WHEELS EVER CONSTRUCTED. ITS VERY EXISTENCE TODAY SERVES AS A LASTING TESTIMONY TO ENGINEERING INGENUITY IN THE ANCIENT ARAB WORLD AND TO THE CENTRAL ROLE OF TECHNOLOGY IN CREATING AND SUSTAINING SUCH SOPHISTICATED CIVILIZATIONS.

لآلاف السنين قبل الثورة الصناعية كانت الدواليب المائية هي الوسيلة الوحيدة التي مكنت البشر من تسخير واستغلال الطاقة بكميات كبيرة. كما مهدت هذه الآلات الطريق لإنشاء الطواحين المائية والطواحين الهوائية ثم التوربينات الحديثة.

تعد الدواليب المائية الضخمة التي لا تزال تعمل على نهر العاصي في مدينة حماة بسوريا فريدة من نوعها من حيث الحجم والعمر. فالناعورة المحمدية يرجع بناؤها إلى سنة ٧٦٣ هجرية (١٣٦١ ميلادية). بقطرها البالغ ٢١ مترا (٦٩ قدما) تعتبر هذه الناعورة من أضخم الدواليب المائية في التاريخ.

إن وجودها اليوم هو شهادة باقية على العبقرية الهندسية للعرب القدماء وعلى الدور المحوري للتكنولوجيا في بناء مثل هذه الحضارات الراقية وإدامتها.

الجمعية الأمريكية للمهندسين الميكانيكيين – ٢٠٠٦

ASME

2006