Bellman hangars: structures of scale and functionality

M. Naudé
Department of Architecture, Tshwane University of Technology
E-mail: mauritz@ditsong.org.za

Industrial buildings and structures are not usually associated with the discipline of architecture but rather with civil engineering. However, industrial structures form an important part of the manmade landscape of the Gauteng Province. The largest concentrations of settlements and sites associated with the manufacturing sector were established in Gauteng, the result of the presence and processing of minerals in the region. This resulted in the occurrence and legacy of a variety of predominantly industrial building types associated with mining, industry and manufacturing. One branch of engineering structures that also occur in South Africa includes buildings and structures associated with the country's military and aviation history. Aircraft hangars, and especially the so-called Bellman hangar, are the most common of these buildings. As the location of most iron and steel manufacturing plants also occur in Gauteng, the construction of industrial structures and the manufacturing of hangars are closely related to the establishment and development of these companies.
Key words: aircraft hangars, Bellman hangars, industrial structures, Second World War, air force bases

Bellman vliegtuigloodse: strukture van skaal en funksionaliteit
Industriële geboue en strukture word nie gewoonlik met die dissipline van argitektuur geassosieer nie, maar eerder met siviele ingenieurswese. Nogtans maak industriële geboue en strukture 'n groot deel uit van die mensgemaakte landskap in die Gauteng Provinsie. Die meeste en grootste konsentrasies van nedersettings en vervaardigingsbedrywe wat hulle ontstaan te danke het aan die voorkoms en verwerking van minerale, is in Gauteng geleë. Die resultaat is 'n verskeidenheid van industriële geboue wat geassosieer word met mynbou, industrieë en die fabriekswese. 'n Ander vertakking van ingenieurskonstruksies wat meer wyd verspreid in die land voorkom, is die geboue en strukture wat met die land se militêre en lugvaartgeskiedenis verband hou - waarin vliegtuigloodse en veral die Bellman tipe, 'n prominente rol speel. Aangesien die meeste vervaardigingspunte van yster, staal en verwante nywerhede ook in Gauteng geleë is, het die ontwikkeling van hierdie industrieë 'n noue verbintenis met die bou en verspreiding van vliegtuigloodse en industriële konstruksies gehad.
Sleutelwoorde: vliegtuigloodse, Bellman vliegtuigloodse, industriële strukture, Tweede Wêreldoorlog, lugmagbasisse

It remains difficult to classify hangars in the domain of architecture as they tend to be associated with civil engineering rather than "architecture". However, an aircraft hangar still remains a "building" as is reinforced by the statement by Pevsner: "Nearly everything that encloses space on a scale sufficient for human beings to move in is a building; the term architecture applies only to a building designed with a view to aesthetic appeal".[1] The Bellman hangar was designed to house aircraft and not primarily for humans, therefore considered to be a building. In addition, the scale of the hangar building type and its almost complete utilitarian character stripped of all aesthetic characteristics are usually not associated with architecture or the work of architects and from a purist viewpoint remain peripheral to the domain of architecture. Another reason why hangars are preferably categorized with engineering rather than architecture may be because they have mostly been designed by engineers, as the storage of planes on such a scale has always been seen as the domain of civil engineering.

However, this does not mean that the design principles of hangars cannot be applied to architecture or any building that enters the sphere of architectural aesthetics. The work of the well-known architect Mies van der Rohe (period 1920 to 1970) and of engineers such as Pier

Luigi Nervi (1891-1979) and Robert Maillart (1872-1940) supplies ample examples where engineering is merged with architecture and vice versa. Even with such fine examples, the common perception remains that the aircraft hangar types, still found at airfields, are clinical shed-type structures. These are the buildings referred to in this article.

The discourse can be approached from various angles; one is to merely describe the history of and background to this particular building type while another may be to reflect on the more universal aspect of large structures associated with this particular period in human history. Other angles would include placing the topic under the auspices of military history of the 20th century or merely the history relating to the Second World War, the history of 'catalogue' architecture and engineering works or focusing on the history of prefabricated materials and techniques during a particular period, e.g. during the Second World War from 1938 to 1945.

Where do hangars fit into the history of large structures? Are they mere sheds, do they have monumental qualities, are they mere containers for manmade artefacts or do they reflect something of the human spirit and its history of designing and constructing large structures?

As the investigation progressed, it became clear that hangars should not be approached from a 'monumental' point of view in terms of representing or memorializing any events or extreme historic 'happenings', but that they should be approached from a more functional point of view. Therefore, it was decided to merely touch on the aspect of monumentality in general and try to select and focus on some of the elements involved in the historic manifestation of large scale structures and apply them to the hangar type in particular. Hangars cannot be classified in the same category as true monumental structures such as the pyramids of Egypt, the Parthenon (or any large structure associated with this period such as the Hephasteion temple (figure 1), Gothic cathedrals, castles and palaces that were erected over time. They remain utilitarian structures of the mid-20th century even though some examples, due to their engineering ingenuity, as celebrations of the free human spirit and as contributions to the history of industrial building design.

Figure 1
The Hephasteion, Athens (ca. 449-444 BC) is a building of monumental scale, similar in form but created to encapsulate other cultural aspects not large 'objects' such as aircraft (source: Architectural Design 1982: 12).

Motivation for the study

Since 2001 the National Heritage Resources Act (Act 25 of 1999) made heritage impact assessments (HIAs) compulsory for certain development projects. Such assessments enforced the evaluation of manmade structures, sites and settlements of all kinds and due to Section 34 of the Act, buildings older than 60 years are protected by law. This resulted in the large scale involvement of heritage practitioners in the assessment of sites and buildings, including engineering structures and installations.[2]

The Second World War ended in 1945 and South Africa, which was part of the British Empire at the time of the War had to play a significant role in Britain's involvement in the War. With the 60 years clause of the South African National Heritage Resources Act structures or sites associated with the War need special attention.[3] Even within this paradigm the legal obligations of the heritage legislation enforces the protection and at least the assessment of military structures older than 60 years – automatically including those associated with the Second World War.

Not all structures with a roof can be classified as architecture, being the art and science of building (Noero 2012: 6 *Architecture South Africa* June July). Engineering and industrial developments in construction technology do not necessarily from part of the study of architecture and the assessment of industrial structures or any construction work that emerged from the designs of civil engineering cannot always be assessed by architectural historians. Engineers are trained to design and not as historians or as historians of their own products. Historic buildings and structures designed by engineers in the South African landscape mostly become redundant without listing or the necessary assessment before they are discarded and sold off as recyclable material.

A huge void regarding the South African history of sheltering structures in the discipline of engineering history and military installations in particular exist. This is partly the result of closed and tight security regulations regarding military structures and any engineering work or designs that were created or were born of military needs – especially during periods of war. The military archives contain extremely informative data but can be accessed only through certain procedures that rely on the researcher's ability to manipulate red tape and administrative systems involved.

Several projects where the buildings at military and semi-military airfields had to be assessed come to mind. A heritage impact assessment (HIA) was done at the Rand Airport (Germiston, Gauteng Province). The airport owns a large area of land, which is typical of all airports that date from the early part of the 20th century. Managing these properties is expensive and it was decided to redesign the existing land development plan for the airport. Some land had to be sold off to industry and related business ventures. The land where this development had to be located contained several old buildings relating to the early years of Rand Airport's history when civil aviation and the South African Air Force shared the same facilities. A training school was located at Rand Airport. The heritage impact assessment identified the last six dwellings that remained on this part of the property and the process was started to either protect them or find another solution to memorialize the histories of the buildings in an appropriate way. Fortunately a portion of land of about 1.2 hectares was set aside for heritage purposes where old planes could be parked and educational and entertainment amenities could be erected to present aviation related aspects to the public.

All South African airports are currently under pressure to be expanded due to the growing demands of the tourism industry (the result of the political changes since 1994). O.R. Tambo International Airport (formerly known as Jan Smuts Airport and later as Johannesburg International Airport) needed urgent upgrading and some of the air traffic pressure at this facility had to be directed to other airports resulting in extreme pressure on all other smaller and formerly lesser significant airports. After the elections of 1994 all the military South African Air Force (SAAF) bases had to be downscaled and their operational strategies were altered from active to passive operations. This had a negative impact on the military activities and training needs at military bases such as Zwartkops and Waterkloof Air Force bases (Pretoria). It also had a negative impact on Rand Airport where the training school was closed resulting in land becoming available for other development and more commercial enterprises. At all these bases the future of the bases and their facilities had to be re-assessed, including the assessment of the military installations such as hangars, creating a need to investigate the history of various hangar types – in particular the origin of the Bellman hangar.

The period 1930-40: a period of 'order'

The development of iron and steel frame structures did not originate in the 1930s but many examples of earlier structures (first constructed with cast iron elements) exist.

The use of iron and steel introduced a new era into the world of engineering and architecture. The 'new' materials allowed larger structures to be erected in short periods of time and the manufacturing of prefabricated sections and elements made it possible to transport these elements to a building site where the structure had to be assembled.

The changes were brought about by the inventions and patents of the Industrial Revolution in Britain and made it possible to construct architectural and engineering structures that were able to create vast covered floor spaces in order to create ample room for a variety of indoor uses. One of the outstanding buildings was the Crystal Palace (London) that was erected in Hyde Park as early as 1850 (figure 2). It was designed by Joseph Paxton and was constructed over a period of five months. The structure covered 19 acres of Hyde Park. It became famous for its size and design but also as an example of the speed and efficiency of construction that became possible when using prefabricated parts and materials.

The history of hangars is linked to the history of aeronautics in Europe and especially the history of Great Britain within its European context after the Industrial Revolution of the 19th century, its role as colonial power with colonies all over the world, and its later involvement in both World War I and World War II.

The 1930s in Europe was characterized by the rising of several dictatorships in countries such as Portugal and Greece. In some places dictatorships erupted into tragedy such as the Spanish Civil War. Dictatorship was the order supported by aspirations for durability, continuity and national identity.[4] Dictatorships are characterized by the creation of a so-called 'new order' often reflected in large-scale building projects and large individual buildings. According to Franco Borsi "in architecture the element of order is inseparable from the concept of monumentality…".[5]

Between the First and Second World Wars architecture experienced various directions and schools of thought. During the 1930s architecture became inundated with decoration and melancholy while some schools (such as the Bauhaus in Weimar, Germany) promoted the complete stripping of embellishment. At the same time beauty was to be reflected in simplicity: the structure and form of a building had to be simple though beautiful in its minimalistic state. Engineering had to serve architecture. It was within this paradigm that engineering as discipline had to expand into both 'architecture' and 'purist' engineering. 'Order' had to be precise and resulted in the well-defined contrast between 'architecture' and 'engineering': 'building' versus 'technology'. In architecture, 'technology' had to be integrated into each of these cadres, each supporting the other while in pure engineering, parts had to be separated and designed either to be modular or purpose designed: the latter being the ideal scenario for the design and construction of hangars. Adding the additional quality of having a transportable shelter that could be either enlarged or made smaller, increased the possibility for alterations to size and scale while remaining sufficient, clinical and retaining strength.

Figure 2
Drawing of the main and largest arched space of the Crystal Palace, which was destroyed by fire in 1939, unbolted and moved from Hyde Park to another park in South London (photograph: Foster 1982: 113).

Following these new paradigms, the 20th century is characterized by a thrust towards minimalism, along an evolutionary trajectory. The drive towards minimalism as expressed in the design of the Bellman hangar was motivated by war and serving an essential need by designing a structure that consisted of the absolute critical components to make manufacturing, transporting and erection easier and quicker.

The 20th century has also been the century of internationalism. Any individual considered to be a member of the avant-garde had to be a product of the city, whose prototype had no roots and traveling beyond ones 'own' boundaries was the driving force and objective at the same time. The flipside of the coin asked for respect of the virtues of the *Heimat* and *Heim* – a common value and ideal on every German's lips. And an aspiration for a 'new' order and new 'universal' order became a strong driving force in each European country. 'Order' implied making distinctions and the first task of order was to 'distinguish' and 'classify', automatically resulting in the creation of classes of 'separation'.[6] It was within this scenario of 'order' that the separation between 'architecture' and 'engineering' evolved.

Possibly part of this split was the move away from classic architecture and historicism and the thrust to create something new, something mostly separate and isolated from classical architecture. To some extent this drive resulted in so-called Modernism – a movement that clearly favoured the purist approach of engineering rather than the more humane approach favoured by architecture prior to this period. The 'clean' spirited approach of Mies van der Rohe and the relationship of his work to classical Greek architecture are eloquently presented and summarized by Norris Kelly Smith:

> I do not mean to suggest that the measured and impersonal style of Mies and his imitators can be regarded as a modern equivalent of the traditional classicism that descends from the Greek temple. While it possesses something of the formal purity and objectivity of that style, it quite lacks the relationship to the word which is essential to the humanizing significance of the ordered architecture of the past. Whereas every part of the Greek temple …has its own distinctive form, belongs to a class of similar and interchangeable parts, and can be identified by name, the Miesian building consist only of rectangles – shapes that have little relation to the human body and which do not come together… (Norris Kelly Smith).

According to Charles Jencks, Mies van der Rohe's Crown Hall on the university campus of the Illinois Institute of Technology (figure 3) can be described as a "….temple carried by four large trusses and seventeen I-beams, [in] major and minor order of construction. The building lacks several classical features: polychromy, ornament, conventional symbolism, statutory and 'named' set of parts".[7]

Figure 3
Crown Hall at the Illinois Institute of Technology, Chicago (1962) designed by Mies van der Rohe (source: architectureandarts.tumblr.com/post/912440662).

The reference to Mies' work as a 'temple' may be deliberate than incidental as it guides us to the association between the historic perception of temples and cathedrals to the 20th century's perception of buildings of the same scale and in some instances an enthusiasm for the same architectural detail and aesthetic. These definitions or critiques on the purist approach of Mies somehow also direct us towards a definition of 'a utilitarian structure' such as an aircraft hangar – even if it is in an opposite direction - way from an aesthetic approach to form giving in general and form giving elements in particular. To the scholar with a tendency or 'free range' attitude towards such statements, the latter quote of Jencks may even be applicable to an aircraft hangar. As much as Mies has become one of the icons of the 20th century Western architecture, he has also crossed the threshold into purist engineering – with a significant difference: the addition of an exceptional sense for minimalist aesthetics through his selection of materials. The latter aspect of design (aesthetics) often missing or only a mere hint in pure engineering structures such as bridges, factories and hangars.

Industrial products

In architecture 'order' involved rationality, an emphasis on classification and 'typology' with architecture broken down into private, public, industrial or military categories.[8] Hangars and other sheds designed for utilitarian uses where large open floor spaces were needed, had the potential to be created with minimal steel structures and could be covered with any industrial prefabricated sheeting. The mass produced products such as steel sections, corrugated iron sheeting, nuts and bolts that resulted from the Industrial Revolution in the 19th century were ideal for this purpose.

One of the key products resulting from the Industrial Revolution was corrugated iron, a principal product in the history of hangar development. According to legend either John Walker in 1832 or Henry Robinson Palmer in 1828 may have been the first to manufacture corrugated iron. The process consisted of rolling out wrought iron sheets of a limited length to a very small thickness and at the end of the process dipping them in a bath of molten zinc – creating 'galvanized iron' (in the 1890s mild steel replaced wrought iron[9]).

In 1934 the South African Steel and Iron Corporation (later known as ISCOR) manufactured South Africa's first iron and steel members. Corrugated iron was only manufactured at the Vanderbijlpark plant (Gauteng) later during the 1940s. South Africa then acquired the ability to use this versatile prefabricated building element for a variety of uses and in vast quantities. Iscor was able to meet the demand for structural engineering steel for the engineering and building industry and it seems to have been an appropriate time and moment in the history of South Africa when Bellman hangars could be manufactured locally and in ample numbers to be exported abroad.

The advantages of steel are multiple:

- Steel provides a fire proof structure and is durable.
- It is exceptionally suited for adaptation and expansion and can be carried from one location to the other.
- It allows alteration in internal layout design with minimum of expenditure.
- Partitions can be erected that are easily removable and require a minimum of internal supports.

- With steel construction it is possible to obtain the largest span with the least height providing the minimum of obstruction to incoming and outgoing aircraft – a feature of great importance in a hangar.
- Holes drilled through the steel frames and sub-frames allow for a variety of coverings that can be used for roofs and side walls for example galvanized corrugated iron sheets, corrugated asbestos sheets (now illegal in South Africa) corrugated Cellactite sheeting and Robertson's metal sheeting.[10]

Of all steel and glass structures, factories epitomize the freedom these materials allow in terms of creating large flexible covered areas for manufacturing workspace. The need for flat floor surfaces and ample light to execute numerous job types is still the major motivation for office space today and the creation of workspace in high density areas guided this need to build upwards, into multi-storey buildings and skyscrapers. However, some uses cannot be stacked and floor space needed to be expanded horizontally.

Even though some effort is made in this article to highlight the period between 1930 and 1945, the oldest all-metal frame multi-storey building with rigid connections to take wind loads is probably the four-storey Sheerness Boathouse in Kent, Britain (1850-1860) (still existing). The designer of the building Colonel Godfrey Greene had previously employed the contractors who built the Crystal Palace (1850-1851: London) and may have been influenced by them. The Boathouse is clad in corrugated iron and it was the first building to use H-sections and I-beams which are standard in structural steelwork today.[11]

On the other side of the Atlantic Ocean, one of the exceptional examples of an industrial structure is the large Dodge half-ton truck assembly plant (1938) in Detroit Michigan. Its uniqueness was endorsed in 1944 when the Museum of Modern Art selected the building as one of the outstanding examples of American architecture. It consists of a large covered floor space where every phase of production occurs on the same floor, on the same level and within a single open space. It has a strong steel skeleton and a lightweight skin of brick and glass on the exterior. The building is of special interest because it was designed by an architect, Albert Kahn. Prior to the American Civil War, most factories were designed and built by the combined efforts of the millwright and owner. Later they were designed by men who referred to themselves as 'mill engineers'. Kahn, who designed this building for the Dodge Division of the Chrysler Corporation, was a pioneer in modern industrial architecture and with his brother Moritz Kahn established the pre-stressed concrete product 'Kahncrete'.[12]

Figure 4
Dodge truck assembly plant in Detroit (Michigan) designed by Albert Kahn and constructed in 1937. The roof structure makes provision for additional light in the central portion of the building (source: Foster 1982: 116).

The crossover from architecture to engineering was not only the privilege of architects but also became apparent with the work of master engineer Pier Luigi Nervi whose engineering designs have also become icons in the architectural discipline. Several projects where he had to span large open spaces applying the discipline of engineering and using structural engineering as point of departure resulted in master pieces, though some have since been destroyed. One of these is the large minimalist aircraft hangar at Orbetello, covering an area of 100m by 40m (figure 6).

Although a building with exceptional beauty in its simplicity, minimalist design and avant-garde approach to solving the problem of creating a large open floor space with minimal barriers inhibiting any kind of horizontal movement into and out of the structure, it remains an expensive solution to the needs of war, when the objective is rather on spending money on the manufacturing of aircraft than a storage facility.

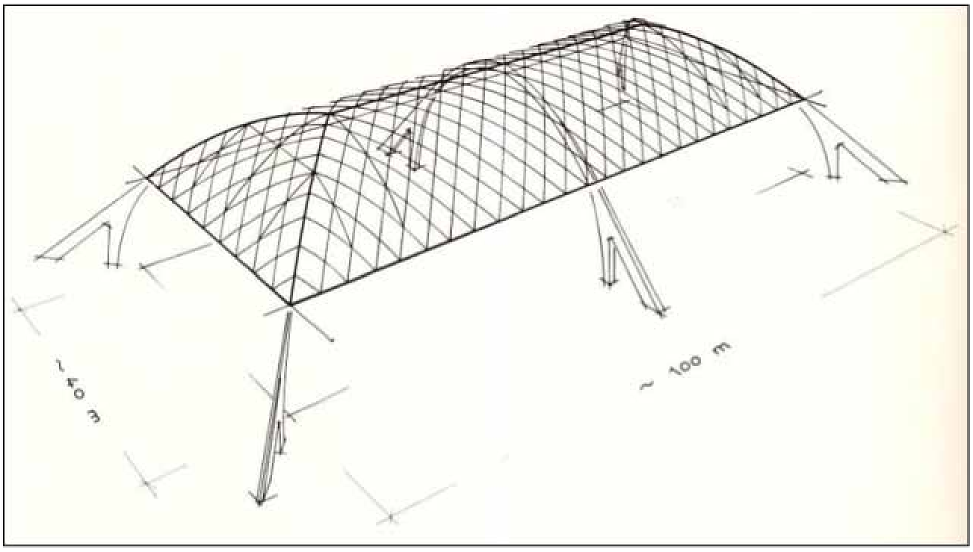

Figure 5
Inverted V-supports of an airplane hangar designed by Pier Luigi Nervi (drawing: Siegel 1975: 155).

However, the rules for the design for a functional hangar type are clearly defined and expressed in the minimal occurrence of columns and supports. The same minimalism seems to be lost in the vaulted roof structure - even more refined when presented in a minimalist drawing (figure 5). The use of the vault also expresses the potential of this very useful form type to cover larger open spaces – so cleverly experimented within Gothic cathedrals eight centuries earlier.

One of the outstanding aspects of this structure is its experimental character and personality even though it does not qualify as a pedigree ‘hangar’ with closed sides and large doors. The building has become a monument for the design of a roof or open-sided shelter but nevertheless addressed and identified the need for minimalist design ‘columns’ to support a vast spanning roof structure. Here ‘security’ and ‘safety’ are of little concern as the need for covered space has been distilled to a single focus and objective for design: to create a roof. The result is a covered space where the inside and outside share the same floor surface, same level and almost no vertical barriers or screens to define the interior or the exterior (figure 6).

Figure 6
Completed structure of an airplane hangar at Orbetello (Italy) in 1939 constructed with pre-cast reinforced concrete. Designed by Pier Luigi Nervi, destroyed during the Second World War (source: Foster 1982: 143).

Structure and functionality

At first glance it seems fair to assume that a hangar only had to be a simple closable 'shed' and the super structure had to be designed in such a way that it does exactly what it is supposed to do: function as a frame to which a light type of cladding can be fixed to operate as mere screens between the interior and exterior. Aesthetics played no role and the structure had no relationship with the discipline of architecture and had no need to serve personal needs or to create humane space. It had to provide space for parking, storing and servicing aircraft.

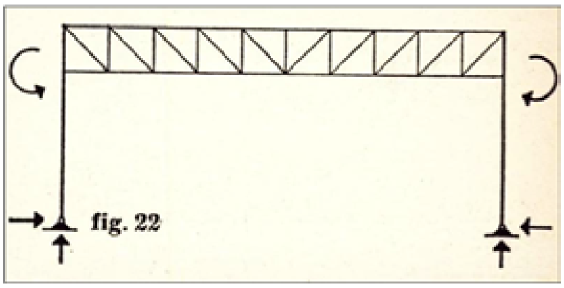

Figure 7
Simple linear steel roof structure supported by thin columns (Drawing: Pestman ca. 1965-75: 17).

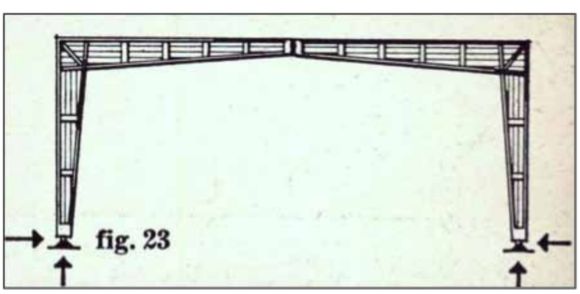

Figure 8
Internal frame with the roof and walls sharing the structural stresses – design for a timber frame shelter (source: Pestman ca. 1965-75: 17).

Hangars had to span large floor spaces and could not be constructed with any supporting members or a superstructure that would impact negatively on the movement of a plane inside the building. Two options existed to solve this problem: (a) use an internal super structure and cover the exterior with a lightweight material or (b) expose the structure to the elements and install the cladding on the inside of the structure. Both methods were used during the war and examples of both still exist. In the case of the Bellman hangar, the entire superstructure is located inside and the cladding or covering was done on the outside leaving the exterior of the hangar almost smooth allowing less wind resistance and protecting the structure from sabotage or damage.

The two options addressed have also been experimented with successfully by Mies van der Rohe, but in its extremely functional and minimalist manner.

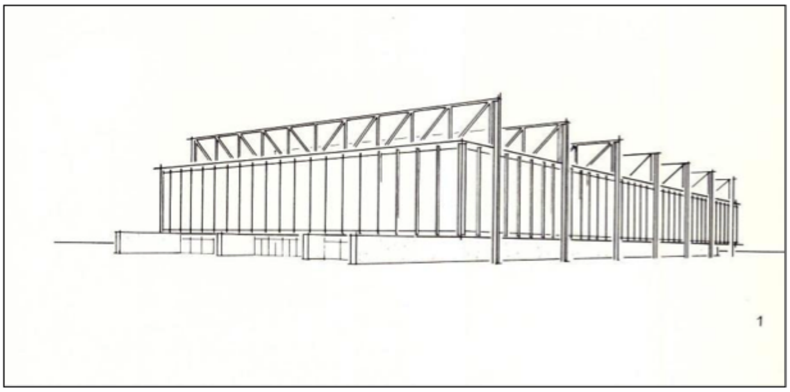

Figure 9
External frame with suspended roof - National Theatre Mannheim, Germany, ca. 1953 (source: Siegel 1975: 181).

First World War (1914-18)

The history of the South African Air Force cannot be separated from the time and political matrix in which the institution was established: when South Africa functioned as a Union and formed part of the British Empire. This implied that whatever happened in and to Great Britain had an impact on South Africa in particular an event such as the First World War. The result was that South Africa and various local industries played a significant role in supporting the British Empire's war effort. The history of aeronautics, the South African Airways and the South African Air Force reflected and endorsed this highly political and strong strategic connection.

Britain was an important player in world politics and was strategically positioned as an 'island' on the threshold to Europe while remaining isolated from it at the same time. During the First World War several hundred airfields existed in Britain. These sites ranged from stations with more than a hundred aircraft to just a landing strip for a detached flight of a Home Defense squadron. As a result there are some thousand sites in the United Kingdom that have evidence of wartime aeronautical activity.[13]

When the Royal Flying Corps was formed in 1912 a standard hangar was used. It consisted of a large timber frame shed with gable front sliding doors and could house three aircraft.[14] In later years some of the wood was replaced by galvanized iron. This replacement was not exceptional nor surprising as its super structure was based on the galvanized sheds used by the British Army as garrison stores at all the 'outposts' of the British Empire. Some of these sheds predate the Anglo-Boer War and were sent to India and trans-shipped to South Africa where they were erected during the Anglo-Boer War (1899-1902).[15]

The Bessonneau hangar was a portable timber and canvas aircraft hangar used by the Royal Flying Corps during World War I. It was designed and manufactured around 1908 by the French rope and canvas manufacturer *Etablissements Bessonneau* based at Anger, but it was called the Bessonneau tent. During World War I it was adopted by the Royal Flying Corps (RFC) to house aircraft in Britain and France. From 1917 these structures were used mainly as temporary protection while more permanent hangars were constructed. After World War I, Bessonneau hangars were often used for cheap and portable storage for civilian aircraft. The use of these hangars by the Royal Air Force (RAF) continued into World War II and remained in use for storing powered aircraft and gliders operated by the Air Training Corps until about 1990.[16]

The hangar was supplied as a kit that could be easily erected, dismantled, transported and re-erected at different locations. The principal material for the framework was wood, joined by wooden plates, steel brackets and steel bolts. Vertical stanchions were used to support the roof trusses with tie beams and ties. A tailored canvas covering was tied to the framework with ropes.[17]

The Second World War (1939-45)

At the end of the First World War it became clear that aeronautics and warfare based on air power and dominance of airspace would play an exceptionally important role and become a deciding factor in any future display of power and serious large-scale military activities. Even though the planes were unsophisticated and most of the bombing and shooting from planes had to be done by hand, it set the scene for several specialized directions in mechanical, civil, electronic and aeronautical engineering. The result of this dynamic scenario, created by the change in warfare, resulted in numerous developments in aeronautics and related types of defense mechanisms.

The developments in aeronautics and the design of new types of planes had to be supported by the design and creation of many infrastructural landscapes where planes could take-off and land. Air stations from where the defense systems of different countries could be managed and used became pivotal points in a landscape that had to be interpreted from a military and strategic point of view rather than from an aesthetic viewpoint. The outbreak of the Second World War clearly defined and increased this need for air strips, military sheltering, strategic and tactical locations and bases. This set the scene for the design of several types of structures related to the discipline of civil engineering – such as new air strips, bridges, hangars and other structures.

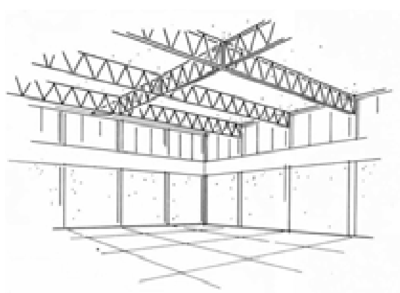

Figure 10
Exposed lightweight lattice joists on the interior similar to those used in the construction of Bellman Hangars (source: Siegel 1975: 181).

In terms of the needs for military purposes and the need for transportability, ease to construct and erect structures, engineering solutions had to be efficient and aesthetics had little or no role to play in the design or the execution of the construction process (figure 10). This was a clear break from the principles and manifestos for commercial and avant-garde architecture at the time. The need for clinical and mere functional structures became more acute when war broke out and decisions had to be taken quickly and construction work had to be executed within short periods of time. The aesthetics of the avant-garde was replaced with the aesthetics relating to camouflage and concealment.

Other exceptional hangar types associated with the period 1930 to 1940 are the extremely large structures erected to accommodate air ships (figure 11). They had to cater for another type of aircraft not at all related to airplanes but had to allow for additional height and volume rather than floor space alone. These were huge "monumental" structures and reflected exceptional ingenuity from the engineering discipline at the time. Compared to these hangars, Bellman Hangars tend to be simple and almost appear to be 'parochial' sheds. The use of the vaulted roof continued to be used and more recent hangars were later constructed using the same engineering principles and architectural form (figure 12).

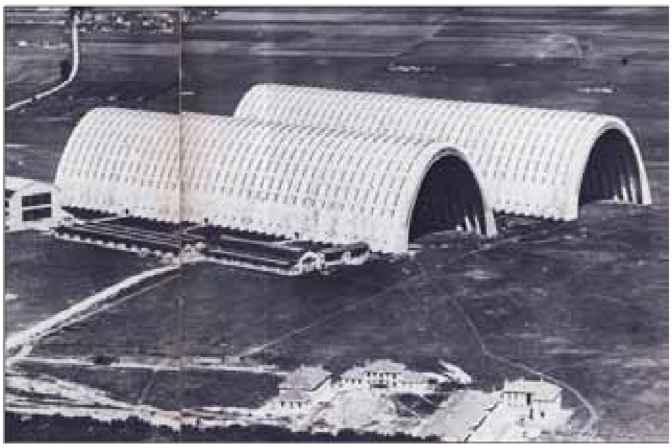

Figure 11
Hangars constructed for air ships at Orly (1916-1924) but destroyed during the Second World War (source: Foster 1982: 141).

Figure 12
Operational hangar (unknown air base in France) of similar shape and form as those erected for air ships of an earlier era (source: Robinson 1980: 153).

The development of engineering solutions towards the creation of simple structures that could cover vast floor areas without elaborate and expensive reinforced concrete construction techniques continued after the war. One of the solutions that became common practice during this period was the introduction of the lightweight so-called space frame structures (figure 13).

A space frame structure is a refinement of previous construction methods and design options. It is a lightweight rigid structure constructed from interlocking struts in a geometric pattern. It is used to span large areas with few interior supports. The basic geometric shape is a triangle and pyramid. A single pyramid is multiplied and used in an interlocking sequence.

Figure 13
The blending of various structural elements of the internal frame structure: the vertical and horizontal frame consists of thin "pyramid-shaped" structures. Sainsbury centre for the Visual Arts of East Anglia Norwich 1976-77 (source: Foster 1982: 122).

Striving towards an engineering objective

Contrary to the designing of buildings during the war, buildings designed on military property and for military purposes in England prior to the war had to be screened for their 'aesthetic appropriateness'.

The expansion of the Royal Air Force (RAF) between 1935 and 1939 provided the Air Ministry Works Directorate with its first real opportunity to design and construct permanent buildings (not engineering structures such as sheds and hangars) of 'character' and uniformity. The first priority of the Directorate was to produce standard building designs for both airfield and domestic facilities. Contrary to later designs elsewhere in the Empire, elevation treatments on all architectural plans for permanent buildings were subject to approval by the Royal Fine Arts Commission. The Commission and the Society for the Preservation of Rural England both shared an interest in the location and placing of buildings in relation to the countryside. A 'Georgian' character was allowed in the design of barrack blocks, mess and married quarter buildings in an attempt to provide 'dignified lines' that would blend into the landscape.[18] This approach was abruptly cut short when the war broke out and the seriousness of full-scale conflict had to be confronted head-on.

Several hangar types evolved due to the pressures and needs for such large structures during the Second World War. Of these hangars, the Bellman hangar was the most significant, also in the South African Air Force history. As aircraft design evolved and planes became larger the need for larger covered floor space also guided alterations to the designs of sheds and shelters destined for military purposes. The need for larger sheds resulted in the alteration of the basic designs and increased the pressure on manufacturers to manufacture sections that could span wider spaces and that could still be transported as easily as the smaller predecessors.

The Bellman hangar evolved from its predecessor: a hangar built by the company Boulton & Paul Ltd of Norwich.[19] It was designed by a group of engineers well-known for designing aircraft. They were the only aircraft manufacturers with a structural engineering department at the time. However, their steel frame structures became common occurrences and were used all over the world popularly known as B & P structures, used for factories, warehouses and smaller examples such as club houses.[20]

Figure 14
Boulton and Paul hangar at Apse Manor Farm built at Shankilin in 1932 for PSIOWA (Portsmouth Southsea and Isle of Wight Aviation Ltd - Britain)
(source: http://daveg4otu.tripod.com/iowweb/sha.html).

The smallest B & P hangar type was designed to accommodate a single small plane and covered a floor surface of 30ft by 30ft (9,2m by 9,2m). Another standard type was larger, covering a floor space of 90ft (27,5m) by 60ft (18,3m) wide and 15ft (4,5m) high. It came with the addition of lean-tos at the back, based on a need determined by the market for attached workshops and offices. The large door allowed access clearance of 45ft (13,71m) wide and 15ft (4.57m) high. A third type was 100ft (30,48m) long and 50ft (15,24m) wide. It was divided into two separate spaces of 50ft by 20ft. For larger aircraft a hangar of 328ft by 82ft wide without any restrictive columns or any other obstructions inside, was also manufactured.[21] One of the distinguishing aspects of the B & P hangars was that the doors could be either located along the side or at the gable-end.[22]

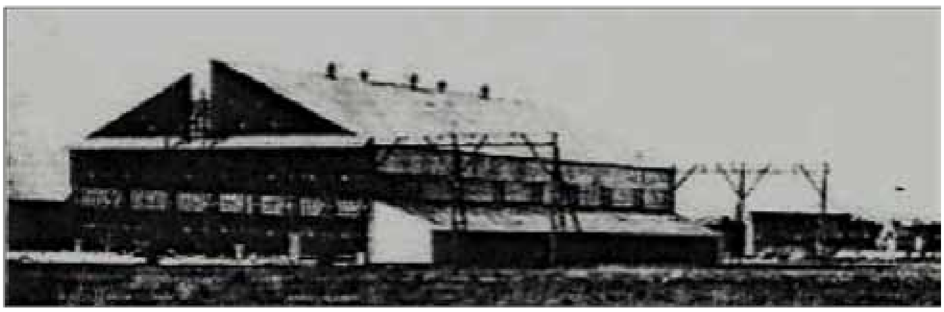

Figure 15
Hangar built by Boulton & Paul Ltd at Rand Airport Germiston (source: Flight 1932: 226).

Specifications for a B & P hangar consisted of stanchions of rolled steel joists complete with caps and bases; roof trusses of steel angles and flats complete with all gussets, shoes, cleats; purlins and girts of steel angles and bracing where necessary. The doors varied according to the size and number of the aircraft to be housed. They consisted of steel frames covered with galvanized corrugated sheeting and ran on a top rack with guides and a guide rail at the bottom. Large high doors had a bottom rail track with guides at the top.[23]

Sheeting for the roof was 22gauge while 24gauge was used for the sides, ends and doors with a 6inch (150mm) overlap. All the nuts and bolts were provided. Un-galvanized steel work was given a coat of paint before dispatch and all sections were checked and tested prior to dispatching to ensure correct fitting. Fitting and construction were made easier by markings to guide assembly on site. Buildings even had gutters according to the measures of each hangar type with stop ends, outlets and straps for fixing. Rain water downpipes were supplied with shoes, bends and clips for fixing. If a hangar was destined for a country with a hot or tropical climate, windows were placed in the sides and the kit was supplied with putty and pegs. In countries with less harsh climates rooflights of patent glazing or glass on puttied steel T-bars were provided.[24]

The most significant hangar type and probably the most commonly known in South Africa is the Bellman hangar. The Bellman hangar was designed in 1936, patented by Mr N.S. Bellman of the British Air Ministry and became the standard hangar type to be used during the Second World War. It was designed to be a transportable hangar as it had to be relocated from Britain to the various colonies of the United Kingdom.[25] Transportability meant that it had to be manufactured in precise sections and parts on the factory floor as no errors could be afforded once it left the factory. It had to be assembled on any of the many air stations based on exact specifications and exact fittings. As South Africa was a Union at the time, it remained a ‘colony’ of the British Empire and therefore benefited from engineering developments in Britain. The Bellman hangar is one of the legacies of this relationship. The outbreak of the Second World War in 1939, resulted in an urgent need for the extensive construction of a hangar type that would suit all conditions regarding accommodation for aircraft and a hangar had to be designed that served this purpose but remained ‘generic’ to the extent that it could be ordered by kit and be erected anywhere in the world. Bellman hangars were the result of this brief.

Figure 16
View of the side elevation of a Bellman hangar with the addition of small windows breaking the monotonous flat wall (photograph: M. Naudé).

Figure 17
The gable-end of the hangar. The gable is structural with no aesthetic function while almost the entire gable end slides open with large steel frame-sheet iron clad doors (photograph: M. Naudé).

Figure 18
Windows attached to the exterior of the building allowing light inside (photograph: M. Naudé).

Figure 19
Large Bellman hangar in front with later model hangars at the back - Zwartkops Air Force base, Pretoria (photograph: M. Naudé).

It was therefore quite fortunate that the design of the Bellman hangar already existed at the time the Second World War started.

Soon after the outbreak of the Second World War, the South African Government decided to establish air schools at various centres in the country and the Department of Defense decided that the Bellman hangar would be the standard hangar type to be erected at these locations. The Government of Southern Rhodesia (now Zimbabwe) was also part of the British Empire air training programme and agreed to use the same hangar type.[26]

The South African Union Government equipped their air schools with hangars that were 95ft (28,95m) wide, 125ft (38,1m) long and 26ft (7,92m) high (height at the top of the doors) while those in Southern Rhodesia were only 50ft long.

The advantages of the Bellman hangar was based on its mobility, simplicity of construction, short period in which it could be erected, and the ease of transporting the various sections. However, this particular aspect is questioned by some authors who claim that the Bellman hangars: "… were costly to produce and time consuming to erect. As a result the Air Ministry, in collaboration with Teeside Bridge and Engineering Works, developed a new 'transportable shed". The author notes that another type of hangar, the T-shed, was designed to counter the difficulties experienced with the Bellman Hangar.[27] The T-shed received its name from the configuration in which planes were parked inside the hangar.[28]

Manufacturing of Bellman hangars in South Africa

As Britain had to secure its own borders and coastline while also safeguarding its major cities and industrial nodes it had to plan strategically. One of the strategies was to have some of the construction and manufacturing of its armaments and structures required for its own war effort to be initiated and continued in its colonies – of which South Africa was only one. South Africa was geographically (not necessarily strategically) almost completely isolated from the war activities in Europe and also had all the essential minerals and manufacturing plants that could enhance, support and reinforce Britain in its war effort. Iscor (South Africa's largest iron and steel corporation at the time) had been in operation for about six years. Numerous other steel related manufacturing businesses were established in support of Iscor and have been in production for the same period. These industries all had the option to benefit from the war effort.

Soon after the outbreak of the Second World War in 1939, four of the leading structural engineering companies in South Africa decided to set up a new company, Dorman Long (Africa) Ltd, which would act as a central body to take responsibility for the ordering and allocation of materials, co-ordinate the manufacturing and attend to all negotiations relating to the supply of materials, the deliveries of completed hangars and all financial and administrative matters. Activities started immediately after the establishment of the central company and manufacturing of Bellman hangars was in progress by January 1940. Dorman Long (Africa) Ltd was deeply involved in work of national importance right from the moment the Government's war production proposals were known. Soon after Dorman Long's establishment, the first move was the formation of Consolidated Engineering Industries (Pty) Ltd, a company established to act as a central body responsible for coordinating all war contracts.[29]

On all the orders on which Consolidated Engineering Industries (CEI) acted as main contractors at least 50% of the actual manufacturing was done by Dorman Long. The two companies were operated in conjunction under the same chairmanship to be able to achieve the best results and efficiency from the engineering industry as a whole.[30] In order to coordinate the supply of separate units, different materials and all other needs for parts and sections of hangars, a special facility was set up for the storage of corrugated iron, glass, sheet metal fittings, erection bolts, and other accessory materials for every hangar manufactured in South Africa.

Complete hangars were delivered just over a month later and soon afterwards were manufactured at a rate of more than twenty per month. By careful subcontracting the production increased to 25 per month. Throughout the entire period of production from January 1940 until the end of 1945 an average of 20 hangars per month was maintained. A total of 915 structures of varying sizes were manufactured.

The value of the new company as a coordinating body on war contracts responsible for distributing work to different companies and manufacturing firms became quite apparent to the Director General of War Supplies, and a few months after Bellman hangar manufacturing was under way, the company was asked to undertake the production of small box girder bridges of which 79 were manufactured.[31]

South Africa remained a supplier of hangars for the war and approximately 50% of the hangars manufactured in South Africa were exported abroad. The remaining number was distributed to various stations in South Africa and Southern Rhodesia where they were used as hangars, maintenance shops, engineering workshops, stores and factories. One South African company, whose parent company in Britain (the pioneers of Bellman hangars), produced many of these hangars particularly for the Middle and Far East.[32]

CEI handled Government orders for a number of projects such as the manufacturing of water carriers and special trucks to carry bridging materials. When airplane hangars of greater span became necessary (larger planes were designed and built as the war progressed) the company made the same production arrangements for 41 of these structures (130ft (39,62m) span by 250ft (76,2m) long) and a special flying boat hangar of 150ft (45,72m) space for Durban was designed and manufactured. A small number of hangar units were also built by a company in Durban.[33]

CEI subcontracted many of the sections of large projects. Between 75 and 80 different subcontractors were located in almost all the major urban centres such as Pretoria, Johannesburg, Durban, East London, Port Elizabeth and Cape Town. The designs and detailed drawings of many of the products that were manufactured by CEI were prepared in their offices or in some of the constituent companies, reducing the pressure that existed in the offices of the Director General of War Supplies.[34]

Dorman Long seems to have been the principal company responsible for manufacturing of Bellman Hangars at their Germiston works and the new workshops that were erected for this purpose turned out a steady flow of these units each month. According to Thomson (et al) few undertakings have been as successful as the production of Bellman Hangars and a standard was set which has not been surpassed in any other line of constructive engineering activity in the Union at the time.[35]

Another company involved in the manufacturing of Bellman hangars was Alpheus Williams & Dowse. The company was formed in 1935 to purchase the structural engineering business of E.G. Dowse & Co. It had a reputation for soundness in structural design and was responsible for the design, supply, delivery and erection of many of the large mine headgears on the Witwatersrand and elsewhere. The company also erected steel buildings, railway bridges and other structures. At the outbreak of World War II the company switched its entire production line to the manufacturing of war related products and supplies. Its newly (1940) acquired Benoni branch was equipped and converted to produce armoured car spares and Bellman hangar units. It continued manufacturing these until 1945 when the Benoni branch was relocated to a site near Germiston.[36]

The new plant, at Germiston, continued to manufacture armoured cars, box girder bridges, Bellman hangar units and a large number of fuel, oil and petrol storage tanks. A significant event during this time was the construction of a hangar in Lourenco Marques (now Maputo). It was the largest of its kind erected in South Africa at the time. However, the second hangar was preceded by an earlier hangar (completed shortly before the war and also erected by Williams & Dowse), that used to be the largest span hangar in Southern Africa. It was also the first large-scale construction outside South Africa in which Iscor steel was used. The second hangar was slightly larger but considered significant because of its large unobstructed floor space of 26 000sq feet (7 924.8sq m).[37]

The materials used for the construction of Bellman Hangars are so-called 'mild' steel sections welded together into transportable building elements. No timber was needed. They also required no foundations or guys. Being lighter than the weight of an ordinary hangar of equal capacity, they could be easily transported to any construction site. Hangars capable of housing the largest type of airplanes used at the time were made locally. They were also designed to be used as storage sheds and some were exported to Egypt and elsewhere for this purpose.[38]

The hangars were made to standard units making it possible to use unskilled labour to be employed during construction. Another advantage was that hangars could be easily repaired when and if damaged either during transporting or due to war activities. In South Africa the structures were clad with plain corrugated sheeting of an 'easy-fix' type. Sheets could be easily fixed in position by the workers who simply had to push the hook bolts through the hook holes provided. The doors were fitted with an overhead track and bottom guide allowing closing and opening without mechanical or electrical support.[39]

The standard units were designed in such a way that they could be loaded onto railway trucks, motor vehicles and mules without the necessity for special lifting tackle. The average number of men needed for construction of these standard units was twelve including the foreman.[40]

All components were positioned for assembly in welding jigs in order to minimize any errors that may occur when assembled. Tests for straightness and quality of the welding were carried out on every unit. All holes were drilled in drilling jigs ensuring interchangeability. Each unit contained several secondary members including bracing units, knee braces, purloins, guides for the rolling doors, wind bracing etc. All corrections indicated by the inspectors were done before the units were painted. Specifications determined that all units needed three coats of paint. Units were dipped in three tanks each containing a different colour. The system was dubbed the 'abattoir system' as the units were suspended on hooks from an overhead rail along which they traveled. Dipping was done with the aid of winches and ensured that each part received its coat of paint. Each unit remained suspended above the tank until dipping was completed. When dry, each unit was transported per suspended rail to the end of the production line where they were stacked and delivered as required. Applying this system ensured that the units of a single hangar could be painted with quick drying paint within 24 hrs. The smaller detail parts of the hangars were dipped in baths of separate colours and suspended in a similar manner to dry.[41]

Conclusion

Bellman hangars are utilitarian structures with historic significance relating to South African engineering history rather than architectural history. The objective to create large covered and unrestricted open spaces still continues and has also become the objective and significant thrust of architecture. The need for the design of large 'containers' for human activities seems to be almost never ending and it is within this timeline that the development of different types of engineering cum architectural 'crossover' structures has evolved.

Hangars are not the only engineering structures that need to be researched and rescued from the commercial drive for demolishing and selling-off of industrial and engineering structures as scrap metal. It is fortunate that they are large shed type structures and that the need for this type of vast 'covered space' is becoming more common. However, their utilitarian and generic spatial measurements as 'covered space' tend to be too large and seemingly too custom-designed to fit into commercial building sites. While the re-use of a Bellman hangar as a warehouse would be cost-effective, it would be less viable to adapt such a hangar for the purposes of a church, apartments, shops or offices. To the man in the street these engineering structures are of little concern as they tend to be negated as useless heritage objects or simplistic structures. Hangars are not considered part of formal architecture, probably because they arguably have no relationship with the designing discipline of architecture. They are not presented in the popular architectural glossies and do not feature in the dense urban environments dominated by the works of architects.

Bellman hangars now qualify for protection under the 60 years clause of the National Heritage Resources Act as all indications are that the production of these hangars was culminated after 1946. They have now become part of South Africa's built heritage and probably form part of a plethora of industrial structures that resulted from engineering (as discipline) and not from architecture and many examples still need to be identified and listed as places and structures of heritage significance.

Hangars will remain engineering rather than architectural structures and essentially storage facilities and will probably never lose their utilitarian character, relationship and associations with warehouses and sheds – those buildings that tend to be avoided by architects though appreciated and enjoyed by engineers.

Notes

1 Copplestone (1983:19).

2 Two Bellman hangars accommodate the majority of displays at the DITSONG: National Museum of Military History in Saxonwold in Johannesburg. This museum forms part of a conglomerate of state (or national) museums and as the Bellman hangars are older than 60 years it is appropriate to determine the significance of these buildings in order to draft an necessary conservation management plan for the site and buildings.

3 The commemoration of the war by the South African Government or any other organization received little attention.

4 Borsi (1986: 10).

5 Borsi (1986: 52).

6 Borsi (1986: 12).

7 Jencks, C. (1982: 9).

8 Borsi (1986: 13).

9 De Clercq, H. (2002)

10 Anonymous. 1932.

11 Foster (1982: 112-3).

12 Sande, (1976: 74-5).

13 Robertson (1983:41).

14 The aircraft used during the First World War were smaller than those developed during the Second World War.

15 Robertson (1983: 41).

16 Http://en.wikipedia.org/wiki/bessonneau_hangar.

17 Http://en.wikipedia.org/wiki/bessonneau_hangar.

18 Congdon (1985: 13).

19 Anonymous (1932: 226).

20 Anonymous (1932: 226).

21 Anonymous (932: 226).

22 Anonymous (1932: 226).

23 Anonymous (1932: 226).

24 Anonymous (1932: 226).

25 Thomson (1946: 64).

26 Thomson (1946: 64).

27 Congdon (1985: 18).

28 This is merely an assumption by the author as no other literature confirms the continuation of production of the 'first' Bellman hangars, neither does any source indicate that the Bellman hangar used in South Africa was also known as the 'T' type. However, the issue has not been cleared yet and needs further investigation.

29 Thomson (1946: 234).

30 Thomson (1946: 234).

31 Thomson (1946: 228).

32 Thomson (1946: 64).

33 Thomson (1946: 65).

34 Thomson (1946: 228).

35 Thomson (1946: 34).

36 Thomson (1946: 345).

37 Thomson (1946: 346).

38 Thomson (1946: 64).

39 Thomson: (1946: 64).

40 Thomson (1946: 64).

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Mauritz Naudé is a senior conservationist of architecture and buildings for historic sites and museums of the DITSONG: Museums of South Africa (Pretoria). He holds degrees in Archaeology, Art History and a Master's degree in Architecture (Conservation). His special field of interest is the conservation of architecture and management of historic sites and museums. Other interests include the study of vernacular architecture, indigenous building materials and construction techniques. For the past 15 years he has been lecturing as part-time lecturer on topics ranging from heritage legislation, museology and conservation of immovable heritage resources at various universities and has extensively published on landscape interpretation, folk buildings such as frontier dwelling types, cone on cylinder huts (rondavels) and timber frame sheds in the region north of the Vaal River.