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PREFACE

Aerotecnica M&S: 100 Years Behind to Explore New Horizons

Preface to Issue 1, Volume 100

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Dear reader,

It is a great privilege to publish the first issue of volume 100 of Aerotecnica Missili & Spazio (ATMS) after a century from the publication of the first volume, in 1921. ATMS was born in July 1920 as the journal of AIDA (Italian Association of Aero-technics and, starting from 1960, Italian Association of Aeronautics and Astronautics, AIDAA). AIDA was founded by 109 military and academic eminent personages, including, among others, Gianni Caproni, Mario Castoldi, Arturo Crocco, Tullio Levi Civita, Umberto Nobile, Modesto Panetti, Vito Volterra, and Guglielmo Marconi.

The initiative of founding a scientific association in 1921 was assumed by scientists and officers of the Italian Air Force after the First World War. They clearly realized that the fundamental role of aviation would have been the civil transport. Their idea was something like prophetic at the time, because military aviation, after the end of the First World War, was destroyed, the technical personnel was dispersed, and the airfields were abandoned. Civil aviation did not yet exist as an organized system of transport, not only in Italy but in all the western industrial countries as well. In this situation, these prophetic founders realized that civil aviation needed to conduct a consistent program of research in aeronautics in peace times; according to them, the future of civil aviation was not, or not only, a lack of financial resources or industrial management but, first of all, of technological and scientific culture. The association was founded in Rome in 1920 to promote research in aviation and to create opportunities for promoting discussions, conferences, and periodic meetings, and to facilitate the cooperation between research and the industry.

During the century, the world has changed as never before in the history of mankind; even more so in the case of aeronautics and space disciplines and in the air transport organization, as well.

The first issue in 1921 of ATMS is the perfect mirror of the state of the art as far as science and technology in aeronautics at that time, worldwide. In this first issue of this centennial volume, Aerotecnica wishes to honour our fathers by remembering the papers published 100 years ago, so that our readers can also realize what the state of the scientific culture was at that time. The journal became one of the most important worldwide one and it has been a reference point of research in Aeronautics. The journal was never interrupted,

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even during the Second World War and some issues were published under very severe security conditions.

The first volume of Aerotecnica in 1921 contained 12 papers, covering the challenges on Structures, Aerodynamics, aircraft and airships, production of light gases (Hydrogen) for airships, and windmills for energy production. The papers were written in Italian in a very elegant language; the titles of the paper (in English) are the following:

- Airplane and airships for the air transport by Prof. U. Nobile,
- Metallic constructions by Col. Eng. R. Verduzio,
- Wind engines by Prof. M. Tenani,
- The "Bresciani" three engine seaplane by Dr. Eng. G. Magaldi,
- The seaplane competitions in Munich and Venice by Dr. F. Grutter,
- The vortex theory in aerodynamics by prof. E. Pistolesi,
- The production of light gases for aeronautics by Prof. G. Gallo,
- The "HH" Hydrogen generator for use in Aeronautics by D. Helbig,
- The safety coefficient of aircraft by Dr. A. Rota,
- The radiotelegraphy in Aeronautics by Maj. Dr. A. Cellani,
- The high altitude flight and influence on human health by A. Gemelli,
- The engine for high altitude flight by Prof. A. Anastasi,
- Italy and civil aeronautics by Prof. E. Pistolesi et alii.

Unfortunately, it is not possible to translate or simply comment all the papers of Volume 1 in details, but, as editorial board of the Journal, we warmly hope that the readers of ATMS would be interested in knowing the level of aviation including methods, tools, materials, ideas, and debates on the future of aviation expected in 1921. In this way, we can verify how the enormous progress occurred in Aeronautics by comparing the flying machines of 100 years ago with the present ones. In this respect, we have assumed a modern disruptive aircraft like Piaggio P180 as an example of modern aircraft and a paper on this aircraft is published in this issue.

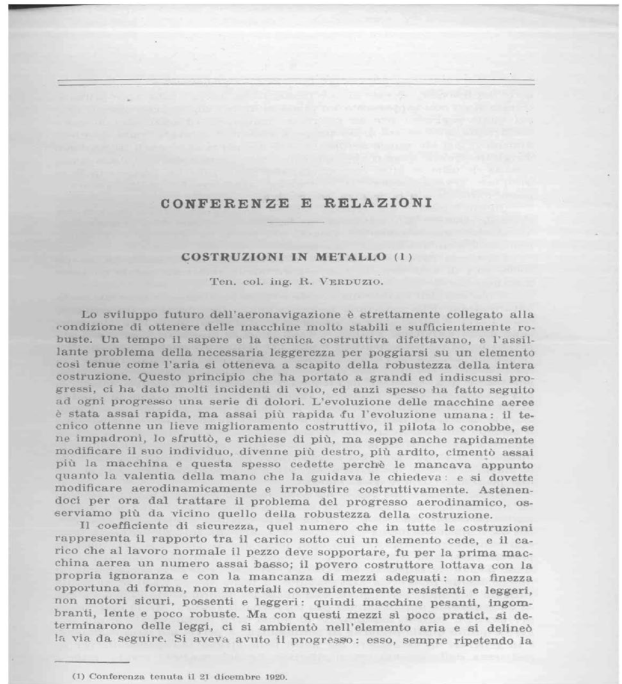
In the preface of the four issues of volume 100, 2021, we will include the translations of one or more historical articles of volume n.1. In the present issue, we start re-publishing the paper "Metallic Constructions ("Costruzioni metalliche", in Italian), by Col. Prof. Verduzio.

A translation from Italian to English of this paper is reported in the following.

Good centennial birthday, Aerotecnica!

Thanks for promoting science and technology in Aerospace worldwide!

Aldo Frediani, Vittorio Cipolla, Sergio De Rosa, Paolo Gasbarri



CONFERENZE E RELAZIONI

COSTRUZIONI IN METALLO (1)

Ten. col. ing. R. Verduzio.

Lo sviluppo futuro dell'aeronavigazione è strettamente collegato alla condizione di ottenere delle macchine molto stabili e sufficientemente robuste. Un tempo il sapere e la tecnica costruttiva difettavano, e l'assillante problema della necessaria leggerezza per poggiarsi su un elemento così tenue come l'aria si otteneva a scapito della robustezza della intera costruzione. Questo principio che ha portato a grandi ed indiscussi progressi, ci ha dato molti incidenti di volo, ed anzi spesso ha fatto seguito ad ogni progresso una serie di dolori. L'evoluzione delle macchine aeree è stata assai rapida, ma assai più rapida fu l'evoluzione umana: il tecnico ottenne un lieve miglioramento costruttivo, il pilota lo conobbe, se ne impadronì, lo sfruttò, e richiese di più, ma seppe anche rapidamente modificare il suo individuo, divenne più destro, più ardito, cimentò assai più la macchina e questa spesso cedette perchè le mancava appunto quanto la valentia della mano che la guidava le chiedeva: e si dovette modificare aerodinamicamente e irrobustire costruttivamente. Astenendoci per ora dal trattare il problema del progresso aerodinamico, osserviamo più da vicino quello della robustezza della costruzione.

Il coefficiente di sicurezza, quel numero che in tutte le costruzioni rappresenta il rapporto tra il carico sotto cui un elemento cede, e il carico che al lavoro normale il pezzo deve sopportare, fu per la prima macchina aerea un numero assai basso; il povero costruttore lottava con la propria ignoranza e con la mancanza di mezzi adeguati: non finezza opportuna di forma, non materiali convenientemente resistenti e leggeri, non motori sicuri, possenti e leggeri: quindi macchine pesanti, ingombranti, lente e poco robuste. Ma con questi mezzi sì poco pratici, si determinarono delle leggi, ci si ambientò nell'elemento aria e si delineò la via da seguire. Si aveva avuto il progresso: esso, sempre ripetendo la

(1) Conferenza tenuta il 21 dicembre 1920.

Metallic Constructions by Col. Prof. Verduzio

Metallic structures were a challenge for structural engineers; the paper is written in a very refined (and somewhat poetic) Italian language as shown in the following: "the development of aviation is strictly connected to the condition of designing very stable and sufficiently robust machines. Once upon a time, science and technical knowledge were insufficient and the nagging problem of the needed lightness to float on a so soft element as air was obtained at the expense of the robustness of the whole construction. This way, we obtained great and undisputed progress, but we had many flight accidents and, seldom, any progress was followed by a set of pains. The evolution of the air machines has been very rapid but more and more rapid was the human evolution: the technician obtained a light improvement of the structures, the pilot discovered it, exploited it, asked more and more but was able also to modify himself becoming more skilled, braver, he stressed more the machine and this collapsed because it was not able to sustain the loads requested by the pilot; the aerodynamics of the aircraft had to be modified and the structures had to be stiffened, …"

The proposed structural solutions integrate the presence of nails and welds (and therefore steel; the introduction of light alloy coatings in aeronautics will be introduced later in Germany) of structural elements in a canvas casing. Later, he says: today, the technique to produce steel and Aluminium spars is convenient and preferable to the ones in wood currently used….and again: it seems premature a decisive judgment whether to give preference to steel over the Aluminium, because this second has not yet reached that industrial development expected. In any case, steel is in its favour of the fact that the elastic limit is higher.

Verduzio is describing the rapid evolution of flying machines during the First World War in the period 1914–1918 and, in this respect, the safety coefficient in aeronautical construction is a decisive aspect for the development of civil aviation; a paper on "The safety coefficient of aircraft" was published by Dr. A. Rota, as said before.

In the rest of this preface, a translation of the paper by Verduzio is presented.

The safety coefficient, the ratio between the load under which an element collapses and the load under service, was for the first aircraft a very low number; the poor manufacturer struggled with his ignorance and the lack of adequate tools, i.e., not appropriate slenderness of the aerodynamic shape, not materials conveniently resistant and light, not safe, powerful, and light engines available and, thus, heavy, bulky, slow and weak machines. But even with these impractical tools available, proper laws were determined, and we became more confident with air and the way to follow became clearer.

We had a progress which, among all uncertainties, led us to the present state of art.

This state is not a point of arrival, but just a step for a greater progress and, today, the modest safety coefficient of the past has become much higher: today, we require a coefficient of 10 for a fast airplane, and 6 or 7 for some parts of a good airship.

These values, which have not been reached by almost all constructions so far, are not, however, an upper limit for the aeronautical constructions; pilots require much more to the construction technique.

This concept seems to be in contrast with the general belief.

How stiffer than a light airplane does appear a building or a locomotive! How much more solid than a fragile airship does appear a car or a ship! Yet, the building, the locomotive, the car, and the battleship have a safety coefficient not higher than that of modern aerial machines.

The need of the very high safety coefficient is to be found in the very nature of the aerial machine. It, hovering over an element such as air, is likely to take on so strong accelerations to result into extremely large efforts, which require coefficients higher than the ones mentioned so far and which, for some aircraft, can assume such high values as to prevent their collapse.

And with a deep acumen, studies are being carried out today by skilled technicians to find a solution to the intricate problem, and some are pushing its conception to the point where it is accepted that the solidity coefficient of some aircraft must be just a little higher than the coefficient of solidity of the pilots. In fact, it is not conceivable that the aircraft should still be healthy when the pilot, for an abrupt manoeuvre, has found death in the air by concussion or crushing! Experience is already being proposed to determine the human stability coefficient, a coefficient which, to our satisfaction, we know to be very high.

This very high value of the safety coefficient needed today has imposed a very accurate manufacturing, studied in the most particular aspects and with material of the highest quality.

The construction, to be conveniently light, needs to correspond to the theoretical model, where each piece works in the way it was designed; any secondary stress is eliminated; any harmful deformation is prevented.

In general, to each failure, it corresponds a new trim state favourable to stability, unless it is a truss under compression, in which any deformation indicates the beginning of an amplifying failure, resulting in a collapse.

However, the elements under compression are normally the lightest and, therefore, the preferred ones in Aeronautics; consequently, any deformation is generally to be maintained within the strict limits for the resistance of the element involved.

Deformations depend on the elastic modulus, so this feature is of the utmost importance in determining the materials to be used in aeronautics. Not necessarily any material with a high deformability must be excluded (wood for propellers is the best one we could wish), but low specific weight, high strength, and high limit of proportionality must be combined with a high value of the elastic module.

Thus, having identified the mechanical properties of aerodynamic materials, we can immediately create two categories. The first one contains those used in parts which need continuity of material and which can be made either as a simple coating, or even as a resistant element. The second category includes materials to be used specifically in resistant elements; in this second category, that has been mentioned above, for the mechanical properties of the materials, finds natural extrinsic and perfect match.

In the former one, on the other hand, the condition of continuity is fundamental, and flexibility must often be added to the previous property, too. Today, we cannot think of an airship, as it is, uncoated with cloth, and to the coating of a ship or fuselage not made of fabric or very light wood plywood.

But if, apart from the specific case of the airship casing (a case to which we will immediately refer), we conceive and agree that the skin must make work, we have a coating that no longer has the property of folding, because it would be harmful, and we can imagine a ship, a fuselage, a wing made of strong plywood or metal sheet.

The case of the airship is far away from the concept to which I have just referred, given its enormous surface of the enclosure, which, at least until now, has to be sufficiently

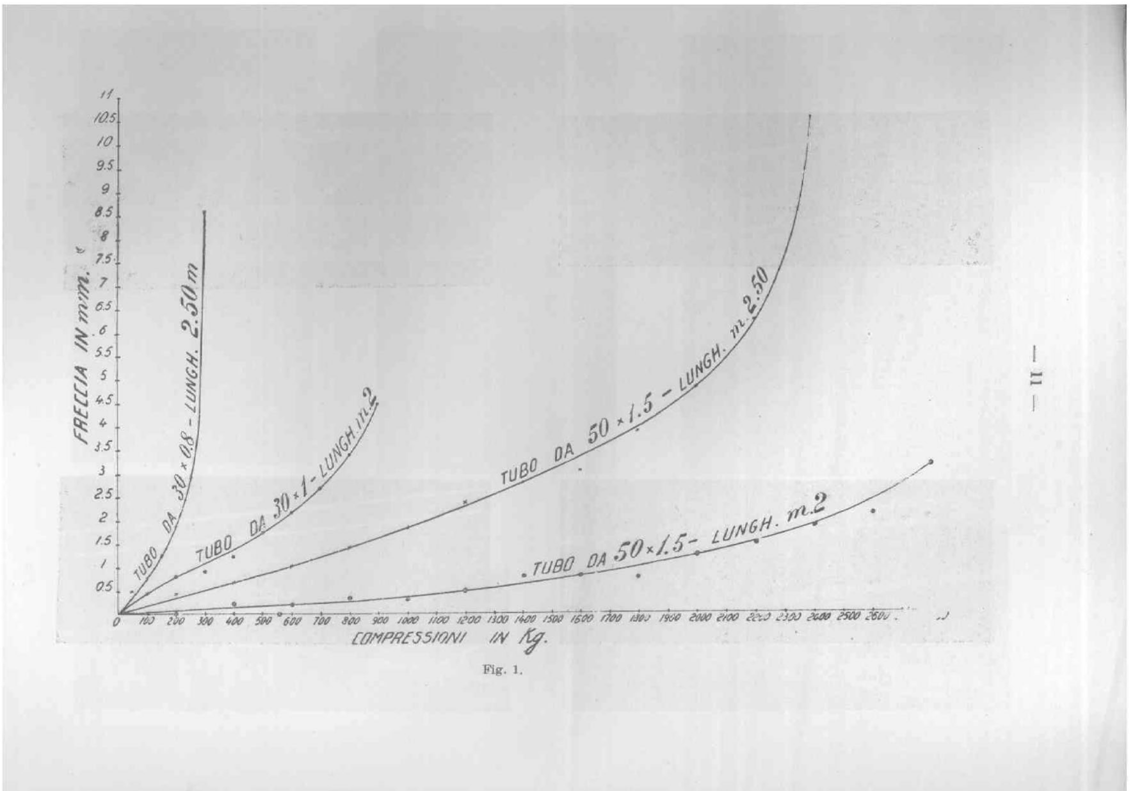


Fig. 1 (From the original paper)

resistant, to concentrate the forces along structural elements. They could not be distributed along the entire surface, because, although resistance to normal stresses would theoretically be possible. It would instead be necessary to concentrate some forces due to secondary and local stresses, breakthroughs, tears, and bends.

Therefore, the floppy casing is flexible by its very nature, and the resistance to working stresses is obtained by the internal pressure which makes the casing sufficiently non-deformable, since any compression is always lower to the existing tension, everywhere.

Apart from the canvas in airships, the aeronautical materials defined as not-flexible to be used in the resistant parts of aircraft are: iron with its binary and ternary alloys, aluminium with its derived alloys, and wood. Others as bushings, supports, etc. are also present for special uses, but these materials, which are not very aeronautical by weight, are used in small quantities and where are irreplaceable.

Wood, aluminium, iron, and derived are not used during this time. The progress which aeronautics had made before the war was almost entirely due to the steel industries. Their progress gave us the powerful and light engine that we needed.

The first aerial machines employed mainly steel, less aluminium, some wood.

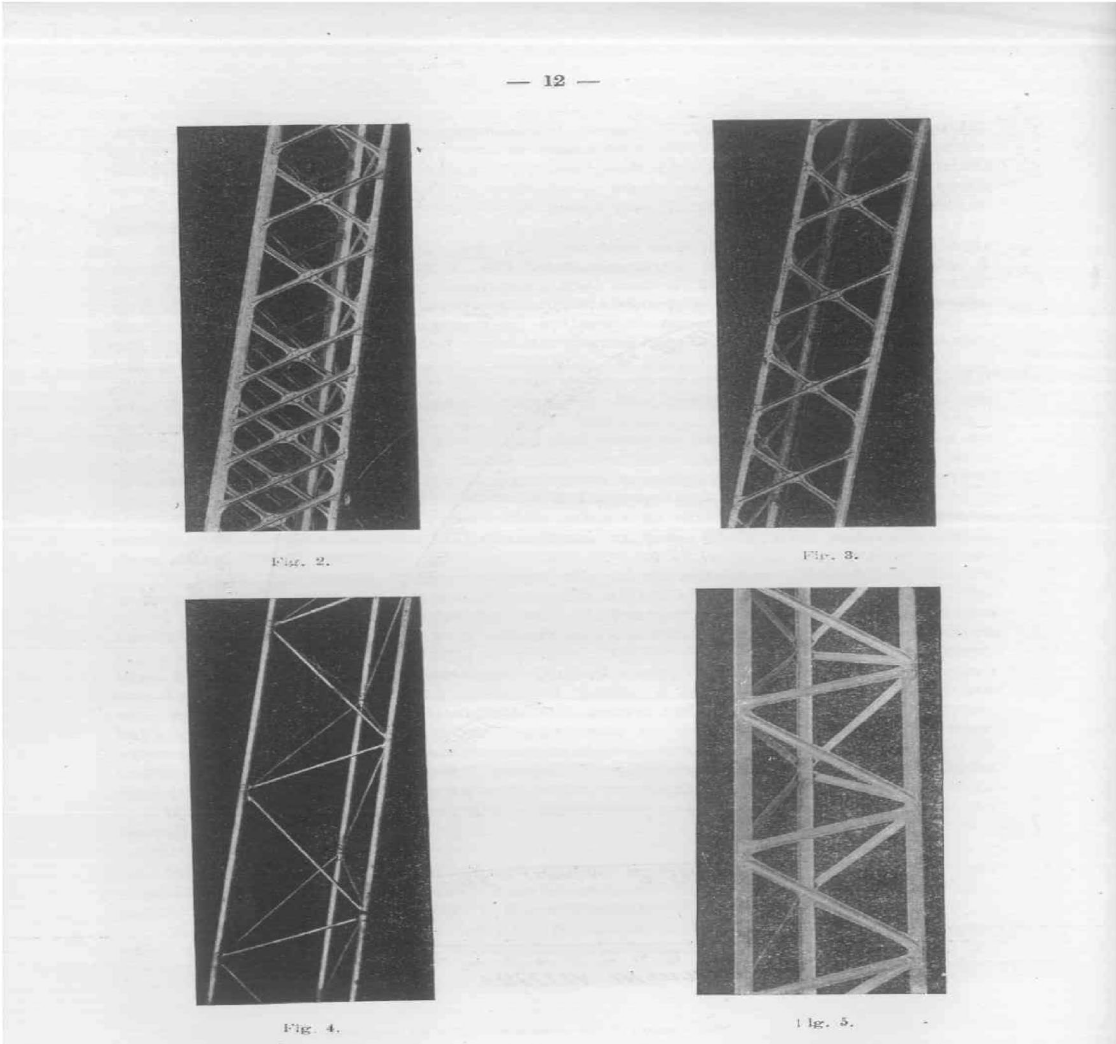
During the war, the need of metals strongly increased for the army at the expense of the air force; this situation, taking also the lack of good mechanical workers into account, led to the large-scale use of wood, and to limit the use of metals only in the irreplaceable parts of the aircraft (the duration of the wooden structures was not a problem, due to the short service life of the aircraft).

Today the problem arises from many other points of view: the commercial aspect is the main one and the machine, in addition to safety, must have a long lifespan.

Wood has drawbacks which metals suffer only to a small extent: strong deformations due to the low elastic module, easy decay with bad weather, easy breaking by chipping, not homogeneous strength, variations of strength and weight from point to point, and ease absorption of humidity with consequent strength reduction.

Therefore, just as every wooden construction subsequently must be substituted by a metallic one, the same is happening for the aircraft structures. It should be immediately pointed out that the privilege of greater lightness in terms of efficiency is no longer valid today, since good steels, aluminium alloy, and derivatives are preferred from this point of view to the best aeronautical woods.

And now let us go a little further and study metal constructions.



Figs. 2, 3, 5, 6 Upper left respectively (from the original paper)

Structures under Compression without Lateral Wind For small loads and relatively small lengths, steel pipes are the best solution, less well aluminium tubes. Theoretically, we arrive at a formula in which we find the thickness, the diameter, and the length of the loaded pipe.

1. The minimum thickness depends on the stiffness against secondary stresses.

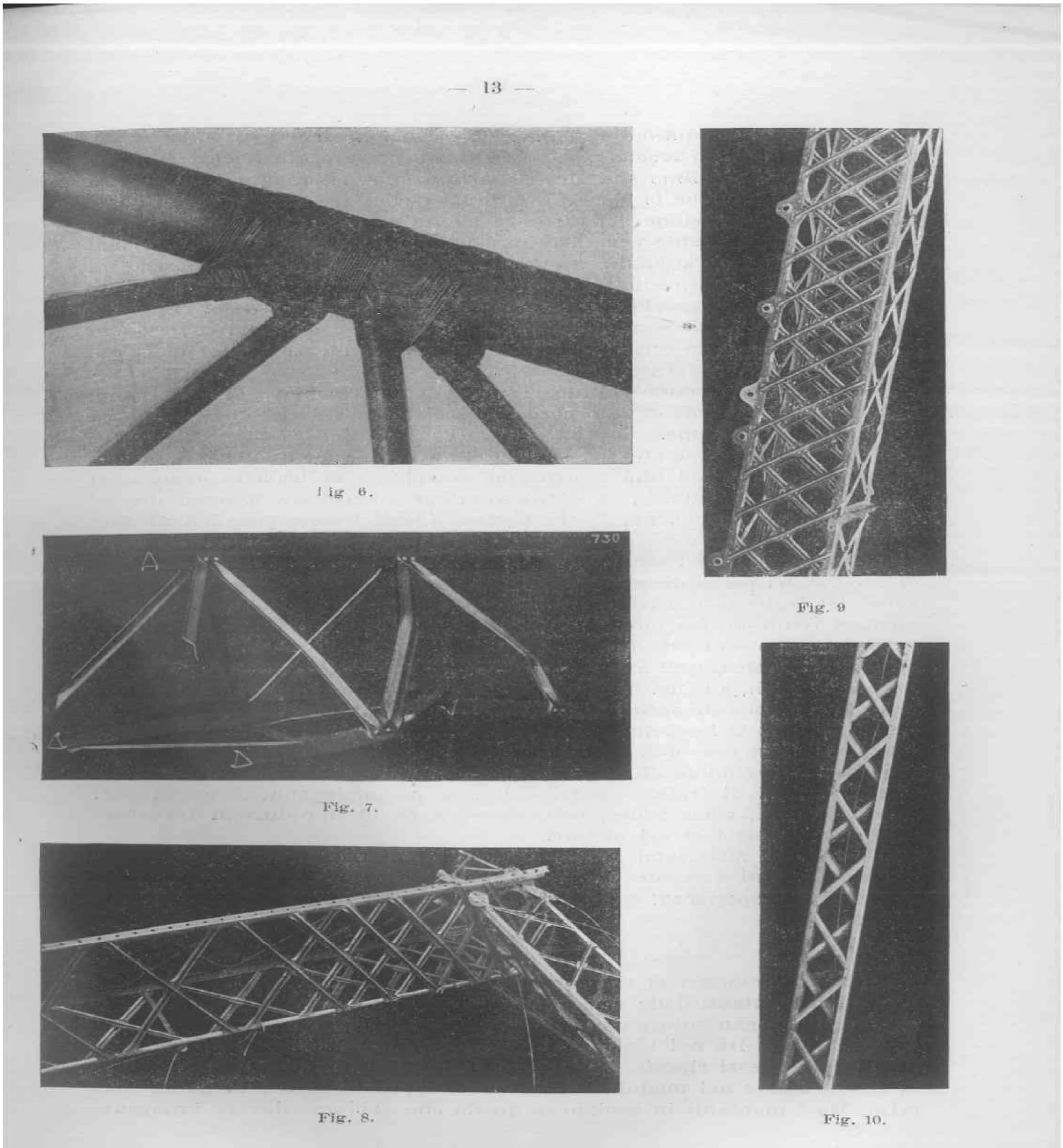
Theoretically and practically, it is shown that this minimum thickness is a function of the radius of curvature, and it can be assumed that it must be no less than 1/20 of the radius of the pipe section.

In these conditions, we accept that it is certainly possible for the present good carbon steels, or ternary steels from 50 to 60 kg/mm^2, to assume a safety load of about 1/5 of the ultimate load, whereas for the aluminium alloy, it is necessary to keep the safety load somewhat lower than 1/5, i.e., to about 1/7.

Subjected to rigorous experiments, tubes such as the ones described have demonstrated the perfect correspondence of theoretical deductions with practical results.

In Fig. 1, we have collected the deformation curves of some tested pipes, and we can realize how small is the difference between the values controlled and the deformation curve.

However, the pipes are not sufficient for high loads and large lengths: in these cases, a complex structural solution is used as the reinforced beam. The theoretical concept is unique, but the practical solutions are different. Usually (Fig. 2), three identical bars are parallel to the axis of the compressed solid and are connected to each other in various ways. The types of connections give rise to the various construction systems. These are the steel tube beams of the first Italian airships and very similar to these are the arrangement of the Zeppelin beams, Fig. 3.



Figs. 7, 8, 9, 10 (From the original paper)

Not all the elementary nodes are suitably connected to each other, and we improved the construction by connecting the various knots together and obtaining a higher strength with the same weight, and, so, we had the steel beams of our present airships (Fig. 4), and the aluminium beams (Fig. 5).

The main difference between steel and aluminium beams lies in the knots; for the former one, a good bandage in iron wire or stagnation (Fig. 6) meets the purpose, for the latter one, a nail with at least two nails is required (Fig. 7), which obliges to use a cold drawn instead of a pipe.

In addition to the previous provisions on the trusses, others are used with equal good results, as seen in Figs. 8, 9, and 10, relevant to trusses quadrangular and lamellar ones, as well.

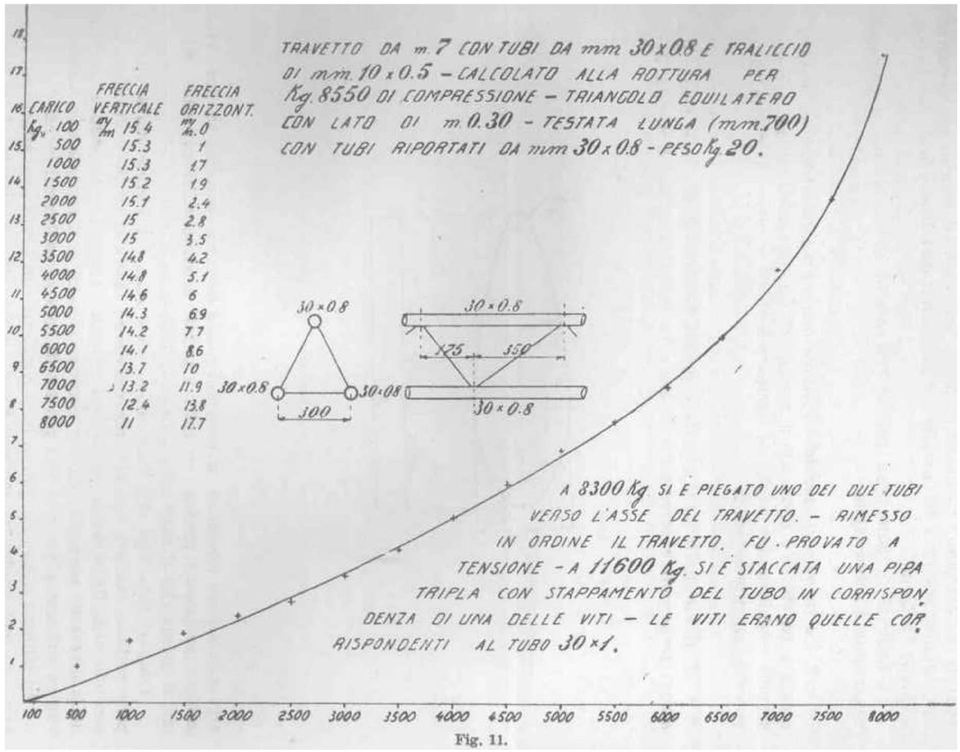


Fig. 11 (From the original paper)

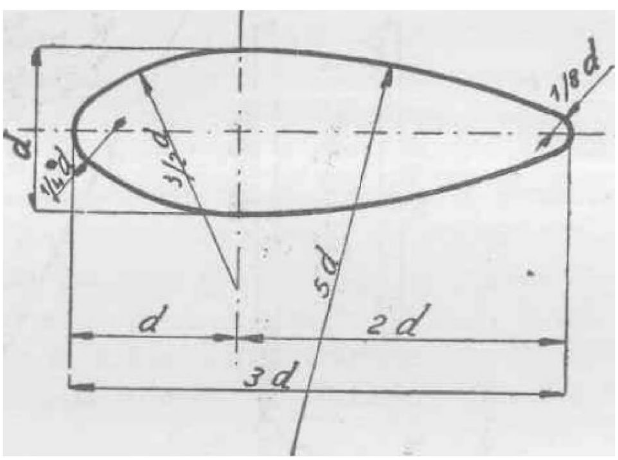


Fig. 12 (From the original paper)

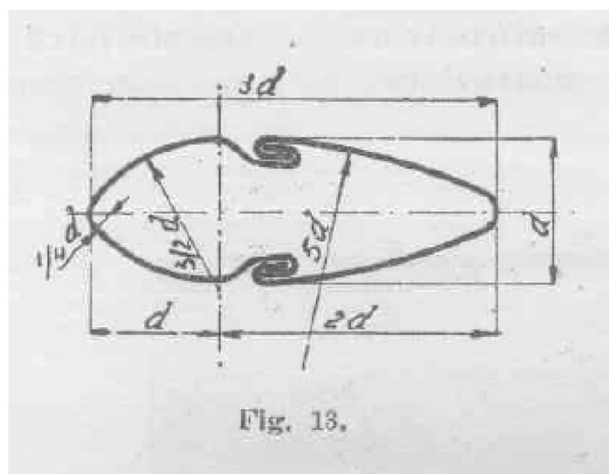
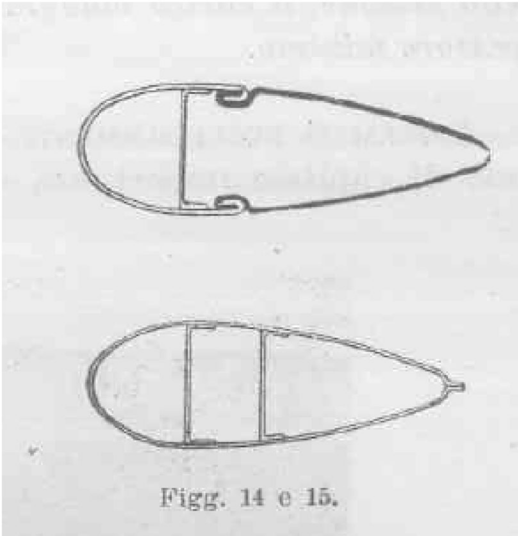


Fig. 13 (From the original paper)

Here, too, we show some experimental results (Fig. 11) on elements tested up to the failure. How rigorous the correspondence between theory and experience looks! Any deformation could be completely verified!

Elements Loaded in Compression and Subjected to Lateral Wind The problem of the uprights of the veiling is very important; it was already studied in the past, with widely used solutions, which replaced wood with steel. Here, the aluminium struts did not correspond to the expectations; the reason lies in the technical difficulty of production and in the (somewhat low) elasticity module of this metal. However, the steel struts behaved well (also considering that the steel we had to employ during the war was of poor quality), so that, in recent times, very few aircraft remained with wooden uprights. The aircraft needed to be aerodynamically improved and the metal strut was preferred to the wooden one.

The basic principles for the construction of uprights can be summarized as follows:



Figs. 14, 15 (From the original paper)

2. The external shape must have the minimum drag, and therefore, good penetration sections are obliged. The circular section of pipes, which would be the best under the compression load, should be properly faired.

3. The upright must be of uniform resistance to the main and secondary actions or, as in the case, the ellipse of inertia must be almost circular and the resistance to secondary bending must be equally great at all points; otherwise, there will be a failure before the material reaches its maximum work. Our tubes (Fig. 12) fit well to the condition of good penetration, but are far from the uniform resistance; in one direction, the strength is very exuberant compared to that of the normal direction; moreover, according to this, the material does not have sufficient curvature to withstand local failure equally well. This disadvantage is somewhat eliminated by modifying the section as shown in tubes, Fig. 13, which we have also used, but they are not fully compliant with the expected results, for the type of structure itself.

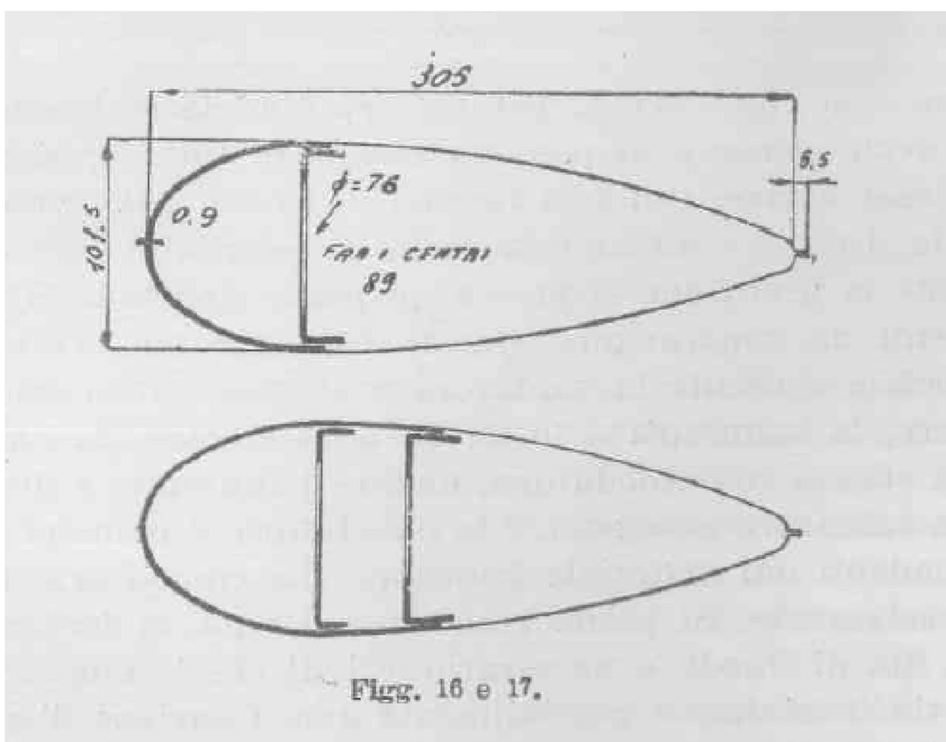
The problem has been technically well solved by the British with a known concept for this type of construction, even though with some difficulties in implementation, to obtain stiffer and lighter uprights than the best spruce wood or steel pipe.

Therefore, upright for small aircraft (Fig. 14) welded and stapled in two halves: the front part, made in steel, is the resistant side; the aft one, in Aluminium, is the trailing edge. Upright for small aircraft (Fig. 15) welded into three pieces made from steel sheet. Strut for large aircraft (Figs. 16 and 17). It seems that there is practically no limit for the design load of them, while the length can be that required for the biggest aircraft existing today.

Theory and experience allow us to establish two general principles which have value for all the rods axially loaded.

4. For axially compressed elements of very small thickness with the same length, same shape of the section, the maximum loads are directly proportional to the thickness.

Figs. 16, 17 (From the original paper)



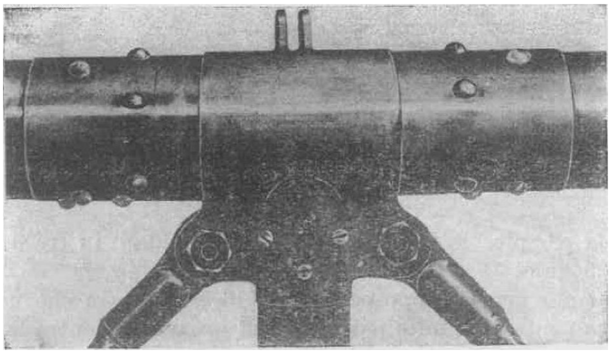


Fig. 18 (From the original paper)

5. For axially compressed elements of very small thickness with the same length, shape, and area of the section, the highest load is carried by the ones having minimum thickness.

Ends of the Elements: Nodes and Articulations These parts, which are of paramount importance in every construction, are especially important in our aerial machines, because from the good positionings of the axles of the elements, all the secondary stresses, which are very harmful, can be eliminated. Here, we will not do the theory of junctions we would have to say too much, we will only be glad to recall the general principles.

Normally, the junction is made with a new piece, which is fixed on the elements to be joined. This fixing can take place in many ways. Steel allows tin welding, with or without iron wire bandage, strong welding, autogenous welding, nailing, and tin welding plus nailing. Meanwhile, aluminium and derivatives allow only autogenic welding, and nailing. The general principles are, however, independent of the material used. The nailing gives only a good junction. Resistance is lost due to holes corresponding to the first row of nails; it is, therefore, necessary that the number of these in the front row is the minimum and possibly one. Nails should be arranged according to Fig. 18.

6. The diameter of the admissible nail is three times the thickness of the sheet to be nailed.

This diameter is larger than the two and a half times as the construction practice teaches for mechanical constructions (due to the very thin thickness of the sheets that we use in aeronautics). Tin welding gives good confidence: it is possible if well done and with holes for tin diffusion down to junctions of 10–12 cm.

7. The better a welding succeeds the better the pieces to be soldered are prepared in advance and the thinner the welding layer between the parts to be connected.

8. To obtain a resistance equal to the sheet or steel pipe to be welded, the welding length must be one hundred times the thickness of the piece to be welded. This welding length can often be excessive, and then, nailing must also be introduced:

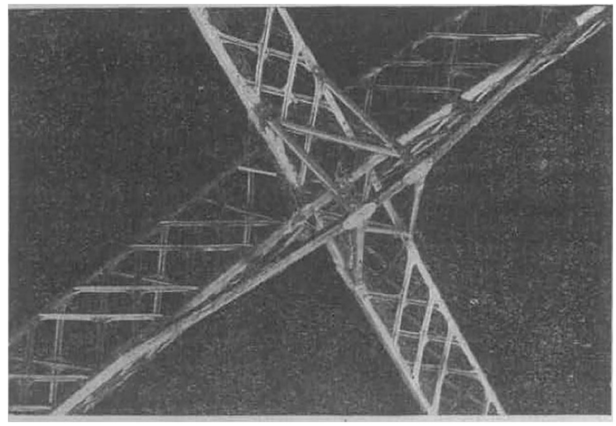


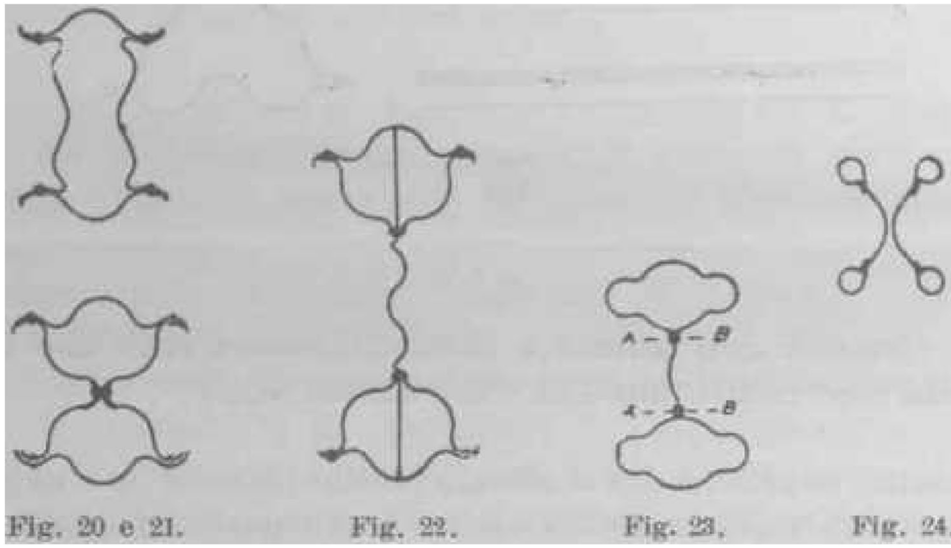
Fig. 19 (From the original paper)

9. The best results are obtained when nailing and welding support nearly the same strength and the first row of nails is as backward from the start of the welding as it needs, so that the force on the welding equals the loss of resistance of the welded piece due to the nails. Sometimes, in adjoint to welding, a wrapping in iron wire (Fig. 6) is also used with excellent results.

Autogenous and strong welding always involves a considerable loss of strength. Therefore, it is possible to use it only in special cases and especially in elements under compression where there is generally exuberance of strength at the ends. In the case of very complex and rigid constructions, the intersection of the elements is obtained by interlocking, often using new parts as shown in Fig. 19, i.e., the intersection of the longitudinal and transverse elements of the Zeppelin.

Spars Elements The superiority of metal over wood is especially clear in the case of wing spars of aircraft and the structures of airships, since in these parts, the compression acts together with bending. The bending deformation of beam under loading is inversely proportional to the elastic module, and the compression load produces a new bending moment due to the lateral deformation; metals are preferable to wood provided, however, that the maximum strength of the metal can be reached.

If the metal has to compete with wood, the thicknesses must be minimal and, given the size of the parts of the present aerial machines, a thickness of 0.35 to 0.6 mm will be required for steel, and from 1 to 2 mm for Aluminium. These small thicknesses lead to local failure that can compromise the stability of the whole construction. To avoid them, we must induce a curvature into the element to avoid local deformations and allow the metal to exploit its full strength. The curvature must consist of light and continuous waves



Figs. 20, 21, 22, 23, and 24 (From the original paper)

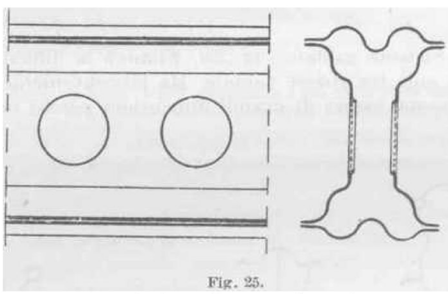


Fig. 25 (From the original paper)

and avoiding sharp angles, where failures will occur. With these concepts, three types of steel and aluminium spars have been proposed: spars with continuous webs, and spars with drilled webs and trellis webs.

The properties of the continuous web are the following:

10 The caps of the spar are continuous without holes, because they reduce the stiffness and we obtain more lightness with small thickness and more curvature of the sections.

11 Absence of nails and other means of connection in the lines of maximum stress.

12 All the metal of the section is working.

13 The borders of the spar caps are curved towards the neutral axis of the beam; the best design of the free borders of the strips is one of the most important problems of the light structures.

The following solutions satisfy the properties mentioned before.

Rudge Beam composed of nailed elements (Fig. 20) (the condition of free borders folded to the neutral axis is not satisfied). Plate thickness 0.01 of the length, web thickness 0.005 of the length, wave radios from 30 to 100 of the thickness, and less in the parts under compression.

Modified Rudge Nailed beam. The two webs are connected in the neutral axis (Fig. 21) or Fig. 22 in the case of higher dimensions. Sometimes, the webs are reinforced.

Dunlop Welded beam (Fig. 23). The disadvantage of this solution is that the tubular parts cannot be large; the advantages are the lack of nails and the folding of the plates.

Double Dunlop Welded system (Fig. 24). It is formed by two bicycle rims that are rectified and connected in the centres. Like the other Dunlop type, it is necessary to strengthen the core to avoid the initial deformations with sleepers at a distance not exceeding 60 times the radius of curvature of

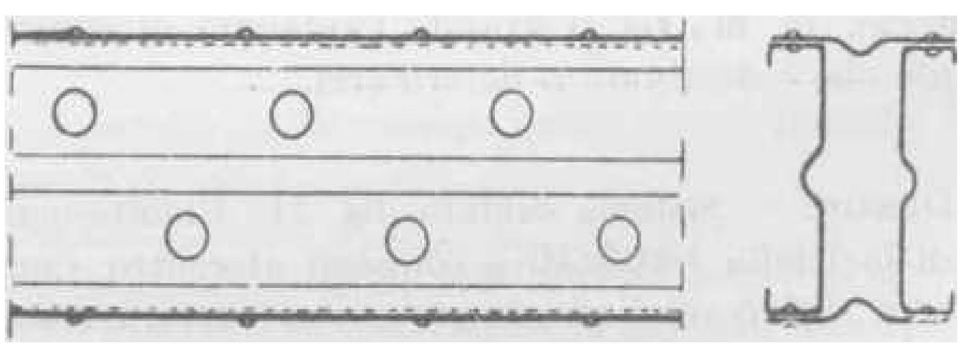


Fig. 26 (From the original paper)

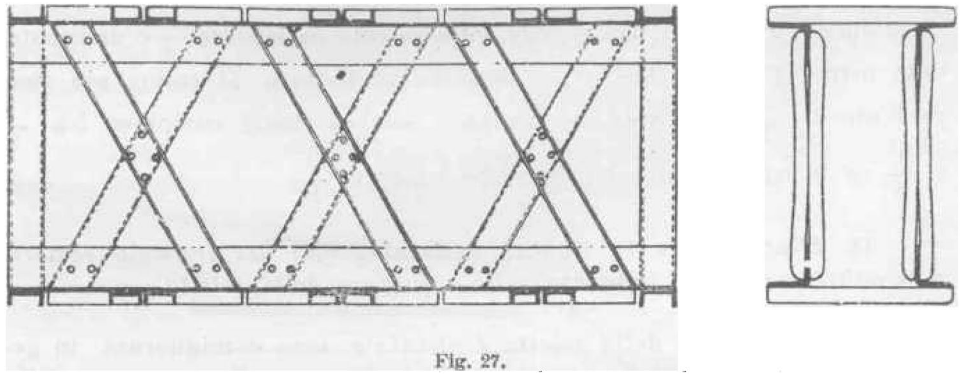


Fig. 27 (From the original paper)

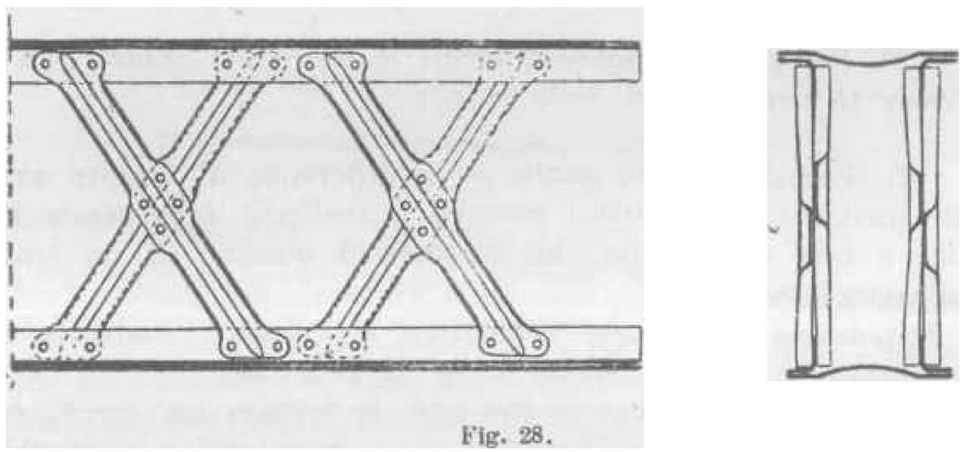


Fig. 28 (From the original paper)

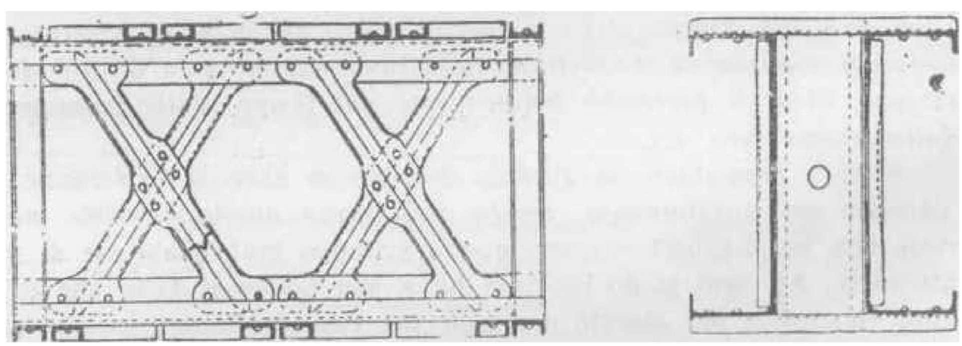


Fig. 29 (From the original paper)

the plate. For hole-core elements, the construction is identified by the same previous properties and the following:

14. It is possible to make plane webs with holes in or close to the neutral axis; the holes are obtained by punching to obtain reinforced borders. Such are the following webs.

Baulton and Paul Nailed beam (Fig. 25). It is similar to the Rouge solution, but now the webs are partially plane with punched holes and with the inward reinforcement.

Humbe (Fig. 26) The section is similar to the wood spar.

For elements with a trellis web, we observe that the characteristic properties that identify the construction are:

15. Exact ratio between the height of the spar and the distance between the points of null bending moments along the span, as not to exceed the weight of the spar caps or of the trellis. However, the height of the beam is imposed by the thickness of the wing.

16. Proper slope of the diagonals of the trellis.

17. Fair proportion between thickness s and width l of the spar cap. If the ratio s/l is too high, the radius of inertia for a given area of the section is small in relation to the distance between the points of zero moment and the collapse of the beam occurs under a small load; if the ratio s/l is insufficient, the failure occurs under small loads due to secondary bending.

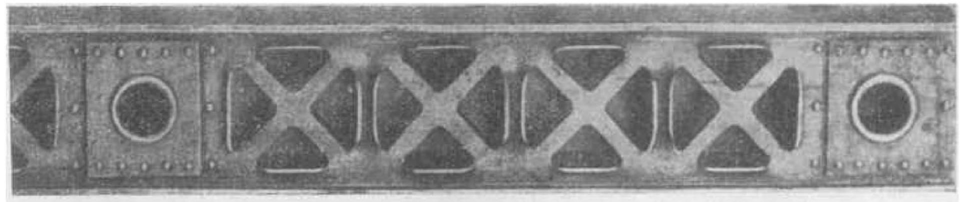


Fig. 30 (From the original paper)

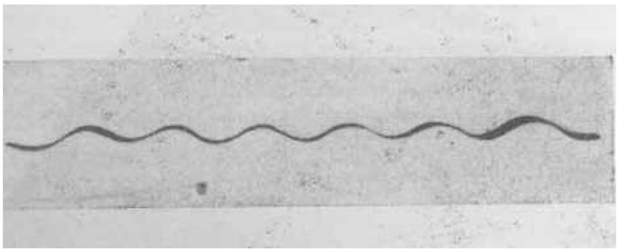


Fig. 31 (From the original paper)

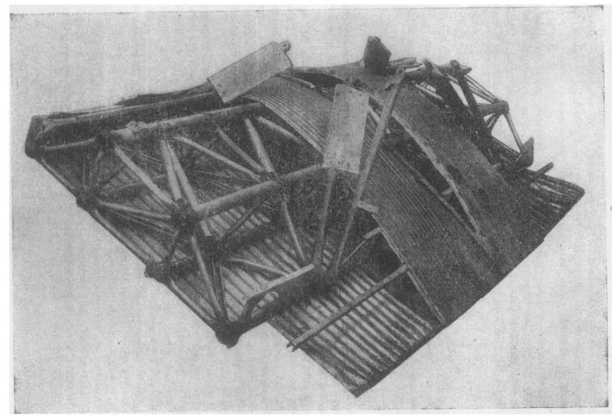


Fig. 32 (From the original paper)

18. The end constraint and stiffness of the diagonals of the trellis do not seem to have much influence on the resistance of the spar caps.

19. The section of the spar cap is wavy; this solution is improved, in general, when the free edges face the neutral axis of the beam.

20. To avoid local deformations, the pitch of the nails must not exceed 15 times the thickness of the plate.

21. Since the shear force is (unlike in the beams of airships) very high, the trellis must be very solid and well studied in such a way that you feel the need for a practically continuous solution.

The solutions built by Pratt and Tempie and by Wickers (Figs. 27, 28, 29, 30) meet these conditions.

It follows from the foregoing that, today, the technique can produce cost-effective steel and aluminium spars, to be preferred to the wooden ones currently used.

By means of the metallic spars, the resistance of the inner part of aircraft wings and of the airship governance plans is guaranteed. Deformations are minimal and the duration of the wings can be considered almost independent of weather, rains, temperature, etc.

It seems premature to make a decisive judgment on whether steel should be preferred to aluminium, because this second material has not yet reached the industrial development which we can expect. In any case, steel has in its favour the fact that the elastic limit is higher and, therefore, in cases of bending pressure can prevail; anyway, it needs extremely thin thickness in size.

Ribs The original designs of two Italian aeroplanes had the ribs built in Aluminium alloy obtained by moulding. These were more solid and with the same weight of those made in wooden, but due to the slender thickness of the metal, they were not very convenient, as they were easily deformable under the impacts to which aircraft veils are subjected on the ground, for the pressure of the fingers and so on. This disadvantage could be eliminated by giving the spar caps of the rib a longitudinal undulation, but, in addition to not giving a convenient support to the fabric, it increased greatly the construction price, and therefore, the wooden ribs were preferable, especially since the latter ones are built with small elements and, therefore, easily found in the processing of aeroplanes.

Structural and Shape Coatings In the Junker light metal airplanes, the Germans have solved the problem of wing and fuselage lining in a truly remarkable way.

They have abolished the structures intended for supporting the external coating by giving it the necessary consistency to withstand the efforts to which it is subjected, and so, the ultralight flat metal sheet has been replaced by an undulation plate with uniform undulations, whose section is shown in Fig. 31, placed along the wind stream. With this system, the full application of the standards expressed above to withstand secondary and local deformations are satisfied. This arrangement ensures a rigidity in one direction and, therefore, allows the skin to maintain the design shape, provided that the skin is connected along the longitudinal lines. The wing skin is nailed to pipes and high thickness structures inside the wing, connected each other to form a robust triangular trellis (Fig. 32) in the wingspan direction. The Junker monoplane has completely cantilevered wings, with no strut or puller. The usual ribs are thus completely abolished and a similar arrangement followed for the fins.

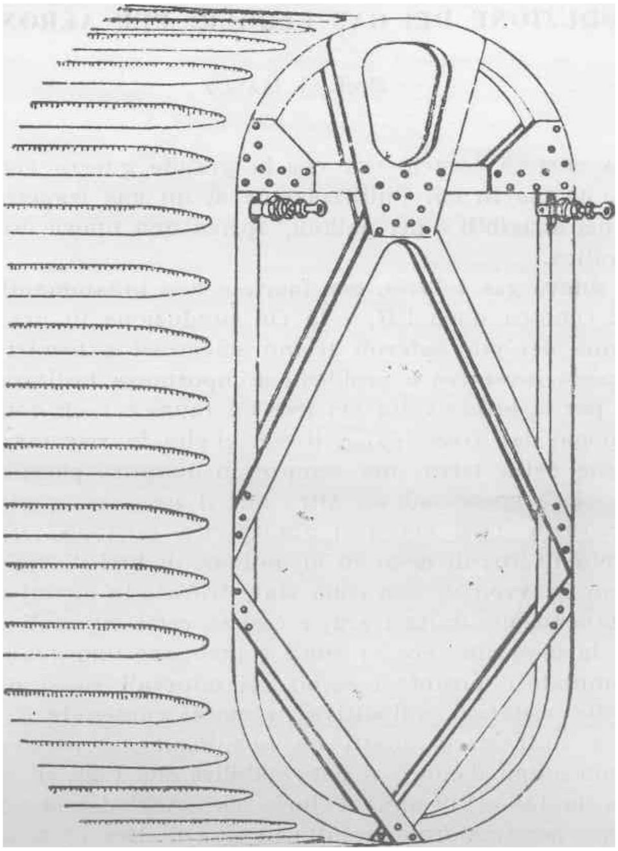


Fig. 33 (From the original paper)

The skin of the fuselage is maintained in the shape of good penetration by metal ribs, whose stiffness is improved by the presence of stiff joints and diagonals (Fig. 33), while any spar and diagonals along the length of the fuselage is suppressed, being the stability provided by the stiffness of the corrugated sheet of coating. It is very remarkable that this type of metal construction, in which it is known how to use skin as a working structural element, must be studied, with accurate and special consideration, because it contains new structural concepts, which can be used properly, and can be of great help the aeronautical constructions of the future. These concepts can be found into:

22. Trying to make the coating as resistant as to support the forces usually applied on the suppressed structure and to exploit the very high strength of the metal.

23. Any modification made to the coating must not increase substantially.

The organs described above include all the parts of an aerial machine. To these, we must add all those that were and will be always metallic, as engines, etc.

Aeronautics has taken a decisive step forward in the study of metal structures, and we are personally convinced that, in practice, they will correspond to the confidence placed in them by the technicians.