Practicalities of loading instruments for Inland Waterway Tankers

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ABSTRACT

Intact and damage stability properties of Inland WaterWay (IWW) tankers are being considered to a much greater depth today than they used to be, because the 2015 edition of the applicable legislation not only requires an extensive (damage-) stability manual to be issued, but also an on-board loading computer to be installed. Although the formal framework is set by the rules, there are quite some issues left for interpretation or additional guidance, where also the classification societies play a role. Besides those practical issues, in this paper also data collection, specific loading instrument functions and loading software assessment are discussed.

Keywords: *ADN, IWW tanker stability, Loading instrument.*

1. INTRODUCTION

After the incident with MTS Waldhof, in 2011, many safety properties of Inland WaterWay (IWW) tankers transporting dangerous goods have been scrutinized. Notably, documents on paper, such as stability booklets and safety plans, but in particular also computer programs dedicated to the assessment of stability, freeboard and strength. As such, these aspects may be suspected to be quite conventional; after all, all required basic tools are standard and readily available. However, some specific properties of IWW ships and their world make loading instrument application less straightforward. In the following sections these aspects are discussed and commented, notably:

- Background of IWW tanker design and the application of loading instruments.
- The regulatory framework.
- Specific functions and features of the loading instrument software.
- Ship data collection and reliability.
- Application and acceptance of loading instruments by crew and management.
- Software assessment and appraisal.

The statements and opinions in this paper arise from intensive involvement of our company with this matter, either by providing services — making designs, preparing stability booklets — or by the preparation and delivery of our ship loading and stability software, see SARC (2013).

2. BACKGROUND OF IWW TANKER DESIGN AND THE APPLICATION OF LOADING INSTRUMENTS

IWW tankers design are commonly governed by these requirements: high volume and dead-weight, low draft, low air draft and favorable hydrodynamic properties. As usual, these requirements are partially conflicting, and recent design methods are not always available. Fortunately, some things improve a bit over time, because in The Netherlands at this moment a four-year research project “Top Ships” is commenced, aimed at state-of-the-art prediction methods for resistance and propulsion of IWW vessels on shallow draft, see Rotteveel (2015, 2016).

From the regulatory point of view, ADN (2015), a classification is made into Gas tankers (type G), Chemical tankers (type C) and others (type N).

Loading instruments are quite common on sea-going vessels, however, until 2013 the application on IWW vessels was in general limited to container ships. After all, since 1986 container ships in the Rhine area have to comply with intact stability requirements, EU (2006), which could in principle be computed manually (e.g. with a table of maximum allowable VCG). However, with a computer it is more convenient, notably if container weights are already available by Electronic Data Interchange.

In 2011 mv. Waldhof capsized in intact condition in the River Rhine, obstructing the river for some two weeks, which caused significant economical and logistical damage, see WSV (2013). To say that mv. Waldhof capsized by lack of stability is tautological, so, it is no surprise that authorities took the initiative to safeguard stability of IWW tankers.

3. THE REGULATORY FRAMEWORK

For safety issues of seagoing vessels IMO, a United Nations agency, plays the role of the international legislator. In Europe, for Inland Waterway Vessels a similar role is played by UNECE, which gather information from different parties, such as flag states, classification societies and the "Central Commission for Navigation on the Rhine" (CCNR). In 1971, the CCNR released the first set of regulations, called ADNR, covering the waterborne transport of dangerous goods, such as chemicals and gas. The letter R in ADNR stands for "Rhine", which was indeed the original applicability of these rules. From 2000 these rules have been generalized to cover transport of dangerous goods on all European inland waterways, and are in force since 2008 under the name ADN. ADN is reviewed on a yearly basis, the latest version is ADN (2015).

Concerning stability, ADN poses criteria of a conventional nature, which require some minimum properties of the righting lever (GZ) curve. Tankers with cargo tanks with a breadth of less than 70% of the ship's breadth are assumed to possess sufficient intact stability, which implies that this ship class is not subject to any regulatory intact stability check. For tankers with wider tanks these intact criteria apply:

- In the GZ curve up to immersion of the first non-watertight opening there shall be a GZ of not less than 0.10 m.
- The area under the positive GZ curve up to immersion of the first non-watertight opening and in any event up to an angle of heel < 27° shall not be less than 0.024 mrad.
- The metacentric height (GM) shall be not less than 0.10 m.

In practice these criteria are seldom critical, compared with damage stability requirements. Damage stability is evaluated deterministically, for side and bottom damage cases of fixed, prescribed dimensions, e.g. a damage length of 10% of ship's length, and for side damages a penetration of 79 cm (type G and C) or 59 cm (type N). The survival criteria are related to the residual GZ-curve, as depicted in fig. 1, and read:

- At the stage of equilibrium (final stage of flooding), the angle of heel shall not exceed 12°.
- Non-watertight openings shall not be flooded before reaching the stage of equilibrium. If such openings are immersed before that stage, the corresponding spaces shall be considered as flooded for the purpose of the stability calculation.
- The positive range of the righting lever curve beyond the stage of equilibrium shall have a righting lever > 0.05 m in association with an area under the curve of > 0.0065 mrad. These values shall be satisfied up to immersion of the first non-watertight opening and in any event up to an angle of heel < 27°.
- The lower edge of any opening that cannot be closed watertight shall, at the final stage of flooding, be not less than 0.10 m above the damage waterline.

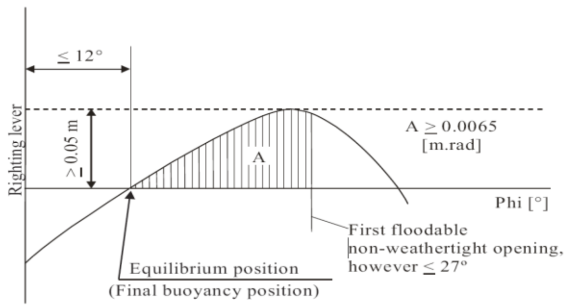

Figure 1: ADN (2013) damage stability requirements.

As such, these stability criteria are quite conventional, and it would be expected that they would not be subject to interpretation differences. However, it took multiple annual ADN meetings before some apparently minor issues have been regulated firmly. Those issues are:

- Watertightness of ventilation openings, such as gooseneck openings or tank vent check valves (as illustrated in fig. 2).

- Watertightness of the accommodation entrance, accommodation windows and the seal between accommodation and upper deck.
- Watertightness of the exhaust.

Figure 2: Examples of automatic closing tank vent device, with floating ball.

Although these "details" may look trivial at first glance, in many occasions they may be of prevailing importance for the economic feasibility of a ship design, see the example in fig. 3, where a damage to the aft cargo region is depicted, combined with a still intact engineroom (ER). The damaged waterline is already situated above deck level in the ER region, treathening potentially critical points, such as windows, doors, ventilation openings and deckhouse seals. If one of these items cannot be considered watertight according to the applicable rules, and the ship's subdivision cannot be redesigned anymore, the only remedy would be a sharp decrease of intact draft, leading to a significant loss of deadweight.

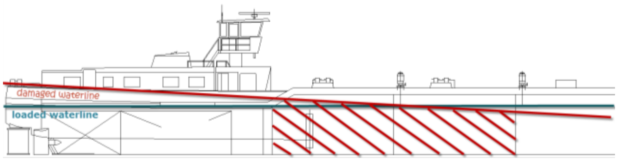

Figure 3: Damaged waterline in aft ship region.

Additionally, by ADN 2015, also longitudinal strength was required to be included in loading software. It is good that these aspects are also included in the safety assessment of an IWW tanker. After all, all required data are already available in the loading instrument, so the additional effort to compute shear forces and bending moments is not high.

By the way, as a side step, it should be noticed that double hull IWW tankers may show a remarkable amount of longitudinal strength. Take e.g. the ship of fig. 4, that sailed right through a weir in the river Meuse, on December 29, 2016. It fell from the weir, some three meters down, and survived without major structural hull girder damage.

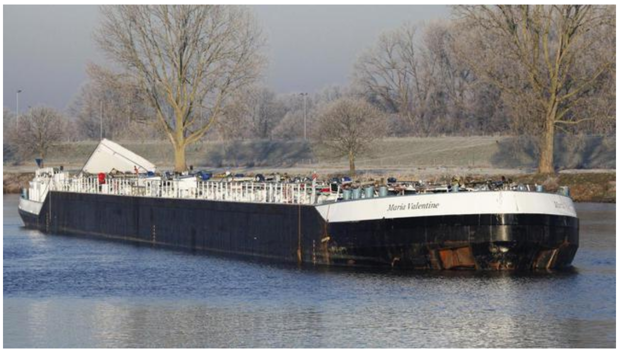

Figure 4: Tanker, just fallen from weir.

By ADN rules, tankers need to be equipped with a loading instrument from January 2015, and should comply with all other ADN 2015 requirements. In order to give the industry the opportunity to gradually process all vessels, a relaxation has been introduced, where this date is postponed until the first class certificate renewal. Because these certificates expire after five years, this implies that by the end of 2019 all tankers will comply, Lloyd's Register (2016).

4. SPECIFIC FUNCTIONS AND FEATURES OF THE LOADING INSTRUMENT SOFTWARE

In general, a loading instrument for IWW application does not differ from instruments for other types of ships. In the course of the years, our loading software has been delivered for general cargo seagoing vessels, naval vessels, offshore platforms, submarines, etc. for which the basis is all the same. Obviously, there can be ship-type-specific enhancements, such as a stinger module for a pipe-laying vessel, a pipe loading module for offshore supply vessels or a periscope module and compression correction for submarines.

Similar specific module for IWW tankers are not required. However, there are five specific computational aspects that play a role in IWW (damage) stability calculation, these are elaborated below.

Automatic propagation of damage case

When evaluating the damage stability results, it might be concluded that a calculation does not comply with the damage stability criteria because an opening of an intact compartment is submerged.

One might wonder what the conclusion would be if the flooding would be extended through that opening. The evaluation of such *progressive flooding* requires flooding scenario assumptions, and is in general still uncharted territory. However, for IWW application, our software contains a provision — acceptable for at least one of the major classification societies — which may result in a larger loading. It is specifically targeted at the requirement that open openings should have a "freeboard" of 10 cm in the final flooding condition, and contains the following steps:

- If a particular damage case does not meet this criterion then the conclusion is drawn "It is yet undetermined whether this damage case complies", and an additional damage case is created where the compartment connected to this opening will also be flooded.
- From these additional damage cases also the intermediate stages of flooding are computed, starting with a filling percentage of 1% for the newly added compartments. This reflects the fact that these are just about to be flooded, but also verifies whether the original damage case meets the other stability criteria.
- Since the flooding through such an opening may take a long time, it is not certain that in all cases assessment against the stability criteria for intermediate stages is allowed. Therefore, in this case the criteria for the final stage of flooding are applied.
- This mechanism reiterates, so, if such a newly generated damage case also does not comply because an other opening has a too small distance to the waterline, then a further additional damage case will be created, etc. etc. Until it is demonstrated that it will comply in this case of progressive flooding (in which case the original damage case complies), or until the ship no longer satisfies another stability criterion (in which case the damage case does not comply).

Computation to SB and PS combined, with integral stability requirements assessment

An elder version of our damage stability software initiated a computation with the determination of the "side with the worst stability" (PS or SB), which is determined with a very simple metric, being the side of the heel. It has always been obvious that this is only an approximative criterion, but for sea-going vessels it was sufficient. However, IWW ships may have a rather asymmetric layout of openings, while openings play such an important role in stability assessment. So, it might very well be that an opening at the side opposite to the heel is critical. This effect can only be covered by a full computation to both sides, which is the standard today.

Maximum allowable VCG method vs. shift of liquid

Traditionally, the adverse effects of free surface moments are accounted in a virtual rise of VCG. This method has the disadvantage that the free surface effect is applied at all angles of heel, while in reality its effect may be limited to the smaller heeling angles. Notably with tanks which are almost empty or almost full. Taking into account the real shift of liquid — both transverse and longitudinal — is commonplace these days, and it is somewhat amazing to see how some people still make do with maximum allowable VCG tables based on the traditional virtual VCG.

Facility to compensate for 'measured' cargo tank volumes

Tank volumes of cargo (and fuel oil) tanks are available from two sources, either based on the "theoretical" (=design) volume of the hydrostatic model, Boolean intersected with the tank boundaries, or based on the "practical" tank shape, as measured from the as-built ship. The latter delivers the so-called "calibrated" tank tables, which are used by shippers and customs. Although in practice the difference between the two sets of tables may not be large, working with different tank volumes is confusing. For that reason the loading software contains a compensation facility, which smoothens out the volume differences, and consequently dampens the human mood.

Hydrostatic - elastic interaction

IWW vessels have a relatively low depth in common, and are consequently relatively flexible. So, their hogging or sagging situation may be rather deflected, which has an effect on deadweight and drafts. Because draft constraints are tight — bottom draft as well as air draft — taking such deflection into account in the hydrostatic analysis will lead to a more accurate computation, which is beneficial to loading and for navigation in confined canals. Although such a feature would certainly be feasible, the interest from ship owners is limited. A factor in this respect is that the official tonnage determination is based on the UN (1966) Convention, which does not support deflection compensation.

5. SHIP DATA COLLECTION AND RELIABILITY

Loading instruments have to be installed on each and every chemical IWW type C and type G tanker, also the elder ones. For that purpose the static ship data have to be collected and defined in a computer-readable format. If drawings are available then this is (just) a matter of digitizing or measuring those drawings, such as:

- A lines plan or body plan, for the hull shape.
- Tank plan or general arrangement plan, for the shape of the internal geometry (tanks and spaces).
- Safety plan, for the locations of openings, and their types.
- Intact stability booklet, for the light weight and its Center of Gravity.

All quite standard, one would say. Unfortunately, more often than once, this data is not available, or not reliable. Notably for the elder vessels. Pitfalls and remedies are discussed in the sub-sections below.

Hull shape

In quite some cases loading instruments have to be retrofitted. If the vessel is of an elder make, obtaining the lines plan may be difficult. If the lines plan is lacking, the hull shape can be reconstructed on the basis of other shape information, such as a tank plan, a construction plan, or pictures. Anything with shape info can be of assistance. Anyway, an advanced hull form modeller is a prerequisite, because an IWW vessel may possess complex shape features, see the example in fig. 5. In the extreme case that no such info is available, shape measurement by laser scanning or photogrammetry, Koelman (2010), could be applied. However, the authors have not yet experienced a necessity to do so for IWW vessels.

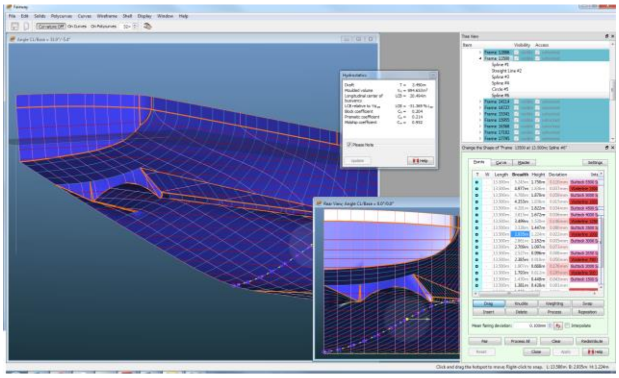

Figure 5: IWW vessel with integrated propeller tunnel.

Tank and compartment shape

Tank shape data, as laid down in a tank arrangement plan, appear to be quite reliable. Sometimes data for small consumable tanks are missing, or tank destinations are mixed up. In general such anomalies can be discovered and corrected quickly.

Openings

People often tend to emphasize on hull shape definition (“where is the lines plan?”). However, in practice other reliable ship data may be harder to find, for example non-watertight openings. A bit exaggerated, at SARC we sometimes say a correct list of openings is more important than the body plan. However, exaggerated? In section 3 it was illustrated that opening particulars can make or break the economic feasibility of a ship (design). Anyway, lists or drawings of openings are notoriously unreliable; the only reliable source is on-board measuring of type, location and connection of openings, an aspect which is also recognized by classification societies, who require independent verification of openings by a surveyor.

Measuring openings is essentially a simple task, which can easily be done with bloc note and measuring tape. However, in practice errors and confusions are easily made. At SARC a dedicated app was developed, from which the system diagram is depicted in fig. 6. This app provides a streamlined procedure, and makes the measurements to be more reliable and more traceable by illustrating them with pictures. The app also make the measurements more standard, and hence less sensitive to subjective considerations.

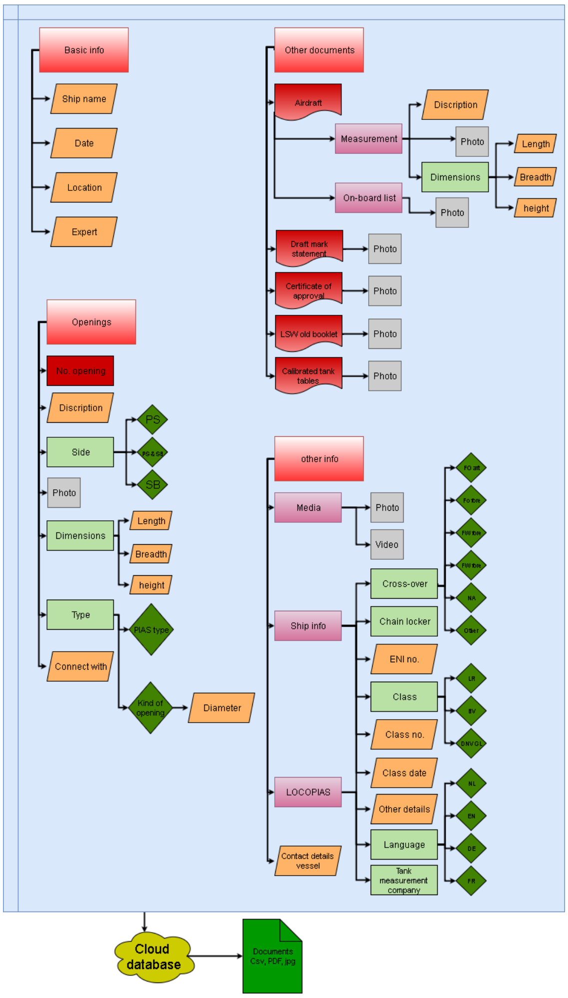

Figure 6: Flowchart of opening measurement tablet app.

Light ship weight, and its distribution

Being one of the most prominent weight items, the accuracy of light ship weight and Center of Gravity (CoG) is of paramount importance. As a rule, these data are readily available from design documents, or from tonnage measurement recordings. However, their reliability is not always guaranteed. Sources for inaccuracies may be:

- Light ship drafts taken for empty ship, without the deflection (hogging) taken into account.
- Light ship drafts taken while the ship is not completely ready to sail. Or the opposite, with non-empty consumable tanks.
- Increased light ship weight during the life time of the ship.

Light ship assumptions that differ from reality will be encountered by a difference in drafts as computed by the loading instrument, and the observed drafts. Such differences may lead to emotional responses by the crew, emailing "your software is faulty!", while the cause can be brought back to inadequate input data. In principle the remedy is easy: "just" enter the correct light ship weight and CoG. However, here is a small caveat. In the form of the classification society that may only accept observed draft measurements (for light ship!) and does not allow reverse engineering of light ship particulars based on drafts as measured for the fully loaded vessel.

As a workaround, at SARC we have developed a form and a procedure that can be used by the crew to a) track the real drafts for a number of voyages, b) convert those drafts into a deadweight constant, and c) add (or subtract) this constant to the pre-defined (and fixed) light ship and CoG of the loading instrument. So, through the backdoor of the deadweight constant — an established concept in sea shipping — the light ship can still be tuned to the observed drafts.

6. APPLICATION AND ACCEPTANCE OF LOADING INSTRUMENTS BY CREW AND MANAGEMENT

In general, management of major ship owners support the implementation of ADN requirements wholeheartedly, which is obvious, because it simply is the law. In one particular example the loading software is integrated with the ship owners' logistic system, where the procedure is such that a ship is only allowed to depart if the loading for that particular journey has been computed and uploaded to that system, **and** if that computation indicates that it complies with all stability and strength criteria.

Crew acceptances are mixed. The majority accept the software and procedures as they are, which will also be assisted by the fact that operation of the software is quite obvious; the Graphical User Interface provides a "what you see is what you get" experience. Others debate the neccesity of these practices, and find it to be only bureaucratic. Particularly annoying is the fact that the software can be produced on the basis of incorrect light ship data, which makes the computed drafts not to correspond with the observed drafts. This phenomenon may make a user to put the correctness of the loading instrument as such in question. Fortunately, with some explanation, the procedure as discussed in the previous section and the deadweight constant, this issue can be resolved.

7. ASSESSMENT AND APPRAISAL

Although all requirements are regulated by national laws and the ADN Convention, the authorities have sourced out the verification of certification to private companies, in the shape of the well-known classification societies. In general, they assess according to the same standards, and occasionally they don't, as illustrated in the next sub-sections.

Requirements for stability booklets and other documentation

Before loading software can be issued for appraisal at a classification society, the paper documentation needs to be ready and approved. This comprises:

- Intact and damage stability booklet. Depending on the software type (VCG vs. shift of liquid) including maximum allowable VCG tables.
- Computations of bending moments and shear forces, and verification against maximum allowable values.
- Damage control plan including all openings. The opening types and locations have to be witnessed by a class surveyor.

Software appraisal

Software appraisal procedures are at the discretion of the particular classification society. One society applies a type-approval process on loading software, which implies that on the basis of some generic test cases a five-year type approval certificate is issued. Additionally, a ship-specific software assessment is required where input data are verified. Other societies have only taken the ship-specific route, they don't offer or require a type approval. In any case the assessment is said to be supported by independent calculations.

Differences between classification societies

In section 3 the regulatory framework has been discussed. This is applicable to all ships, regardless of the classification society. The ADN committee decides annually on uniform interpretations, so that list is growing in time. Nevertheless some differences between classification societies remain to exist:

- A requirement is that the draft marks are not submerged. Differences are that some societies are satisfied by not submerging the average of PS and SB marks, while other stipulate that not a single individual mark may be submerged.
- Similar differences are imposed between booklet and loading software. This may lead to a loading condition in the booklet that complies (and is accepted), while the same condition in the loading software does not comply.
- Watertightness of the exhaust pipe.
- Maximum allowable shear forces and bending moments. These are determined on the so-called Read-Out Points (ROP). Some societies provide maximum values only for midship, or on ROPs in the midship region, so no limits are imposed on the aft and forward extremes of the ship. Other societies linearly interpolate their maximum values between the parallel midbody value, and zero at the extremes. As illustrated in fig. 7, where the curved (red) line represents the actual bending moment. If the maximum allowable moment is simply assumed to be linear between points A and D, a small local exceedance of that maximum appears, leading to non-compliance. However, an analysis with a finer step size will show non-linearity, in a trend according to curve A-B-C-D, and hence lead to compliance. So, the conventional analysis can be a bit coarse and consequently somewhat unrealistic. As if the aft peak would break away from the vessel!

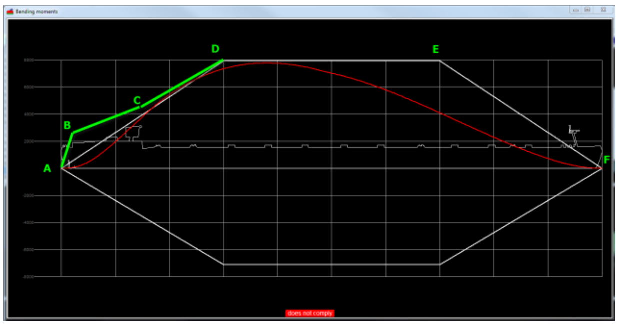

Figure 7: Actual and maximum bending moments.

Additional discomfort occurs sometimes when individual surveyors impose requirements that differ from their colleagues, or from the "company standard". However, with some smooth talking, or reference to earlier projects such issues can often be resolved.

8. CONCLUSIONS AND RECOMMENDATIONS

An overview has been given of factors that exercise their effects on intact and damage stability assessment of IWW tankers, and on loading instruments for those ships. Although no specifically advanced theoretical concepts are required, the involvement of many actors — national authorities, the ADN Convention, ship owners, crew, shippers, classification societies, consultants, ship designers and software suppliers — made that it took some time to reach general consensus. Details thereof, and the standard from today have been sketched in this paper.

It will not be easy to change one of the bricks in this edifice. Having said that, the authors take the freedom to propose a few improvements:

- Relax a bit on the dogma that a class-witnessed inclining test or light ship survey results in the only truth of light ship particulars.
- Allow for taking into account the effect of hogging or sagging into hydrostatics. And consequently modernize the 1966 Tonnage Measurement Convention.
- Stimulate that more ship owners apply the good practices as touched in section 6.
- Increase awareness of the importance of keeping openings closed, such as doors and hatches. And enforcing these issues a bit more strict.
- Don't fall back on traditional computation methods where state-of-the art alternatives are available, as they have been discussed in section 4.

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