THE ROYAL INSTITUTION OF NAVAL ARCHITECTS
AUSTRALIAN BRANCH.

"EXPERIENCE OF COMPUTER CALCULATIONS IN SHIP DESIGN AND PRODUCTION."

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Precis by

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22nd July, 1970.

General remarks:

In this paper, references, specimens and examples are given from programmes devised by DSRI and other centres.

It should be noted that the examples shown may be superseded later by newer issues where the properties of the specimens herein discussed may no longer apply.

Examples are only given to indicate the principles involved.

Illustrations are numbered in accordance with the original paper of which this is a precis.

Abstract:

This paper reviews some of the virtues and desirable properties which should be inherent in good shipbuilding computer programmes and their production.

Introduction:

The application of computer techniques to theoretical ship calculations has been a tempting prospect since these techniques were first developed as a commercial possibility.
Initial proposals for using digital computers for stability calculations were made by Adams (1) [x] in 1949. In 1954 Commander Vasam (2) of the United States Naval Service presented ideas for the use of electronic computers in the Shipbuilding Industry. Shortly afterwards the computer "Besk" was built in Stockholm by the committee for mathematical machines from drawings prepared in the United States. Mr. Kantorowitz, a Danish graduate, prepared his first hydrostatic programme on this machine in 1957.
The first Danish Computer "Dask", modelled on "Besk", was built and during 1957-58 a number of programmes were recoded to suit it.

x) Figures in brackets, refer to the bibliography at the end of this paper.

The Danish Shipbuilders Computing Centre, established in 1958, primarily to supply computations to Danish Shipyards and Shipping Companies, was almost immediately called upon to extend its services to other countries. In the first half year of its existence the centre computed 20 vessels.

In 1963 the Shipbuilders Computing Centre was renamed the Danish Ship Research Institute and computations were produced on the first transistorized computer, the "Gier". By 1965 about 300 vessels per year were being computed and at the close of 1969 a total of 2,700 vessels had been computed and the Lines of 215 vessels faired.

Development of the Institute's Fairing Programme was commenced in 1960 by Mr. Kantorowitz. First coded for "Dask" the programme was later recoded for "Gier". In the light of experience and the wide use of the programme throughout the world it has been developed and supplemented for simplicity and ease of use in the daily run. To-day the programme caters for plate development and numerical cutting.

Since 1958 a number of "centres" in various countries have offered solutions and programmes, and ample description and publication of these programmes have been given, both of detailed solutions and programme experience.

There is, therefore, no particular object in adding to that already available, but rather to give on the basis of experience gained since 1958, a summary of the virtues and qualities that should be inherent in such programmes and their developement that are both useful and valuable from the practical view of shipbuilders and repairers.

1. Precise definition of input data for entry on preprinted data form.

Since the inception of computer calculation techniques one of the major sources of error has been incorrect input data manually compiled. Even the best of programmes will fail if extensive manual work is required to complete the input data.

One method of reducing input errors, is to provide clear and concise data forms, thus removing possibilities for error due to misunderstanding exactly what data is required.

A second essential is to ensure that the volume of data is the minimum required and to arrange the programme itself to keep the data input to a minimum, but still adequate to provide an output of a sufficiently high standard.

Therefore, the production of any new programme must start with the development of easily understandable data forms requiring the minimum of data. This illustrated by examples.
Fig. 1 shows a suitable method of defining the body of a vessel for a specific computation. The hull is broken up into a number of parts, two portions above and below the height B, an after part and also appendages (3).
A further example is illustrated in fig.2. Here each frame or cross section is defined by offsets, both horizontally and diagonally, giving an accurate definition of the hull shape by utilizing the large angle of intersection between the line of offsets and the section (4). This approach has now been superseded by other methods.
A third method defines the frome or section shape by a combination of a trapezoid, arcs of circles and the corresponding distance between the mid-point of the arc and the trapezoid.
Use of trapezoidal integration does, in some instances, result in comparatively complex programme sequences because of the introduction of the arcs, necessary to give a reasonable approximation of the frame shape, and a necessary equivalent to that when using Simpson's first rule.

Therefore, the initial measured input data must be partially transformed into a compensated parabolic form which can complicate the programming, test and fault detection.

Slides 3 and 4 are data forms for a method (6) which uses a parabolic arc approximation to the frame shape between consecutive pairs of section or waterlines.

Slide 3 show the hull split into pairs of equally spaced waterlines and frames, with closer station and waterline spacing introduced in areas of pronounced surface curvature. Slide 4 is the associated data form.

To permit the variation in spacing, the programme can handle 19 sections and 39 waterline variations in the spacing, which have been sufficient to handle all the requirements of the 2,700 vessels computed to date.

The advantage, over the evenly spaced manual calculations, of variable spacing to more accurately define areas of excessive curvature is self evident. Simpson's 1st rule, moreover, simplifies the detection of computation errors and the simplicity of the data forms permits persons, with little or no knowledge of the computer techniques involved to provide the essential accurate offset data from the ship's plans.

As an indication of the variation possible, depending on the hull shape, in some cases the data provided is for 60 stations with a maximum of 50 waterlines (5), whilst another computer centre (6) preferred 79 waterlines in combination with a maximum of 39 stations.

The Classification Society, Germanischer Lloyd (7), required that the number of sections used should be about 30. Vertical inflection points, knuckles, chines and regions of large curvature should be accurately defined.

30 stations, 30 waterlines and 50 other additional figures would result in an input of some 950 numbers, or more generally, between 700 and 1200 input offsets.

This rather high number certainly requires carefully checking to ensure that the data is correct.

As has been mentioned, some programmes for the computation of areas and moments use Simpson's 1st rule (see fig.5) which assumes that the curvature between ordinates is parabolic.

Therefore, a drawing machine directly coupled to the computer can produce a continuous series of parabolic curves between each pair of waterline spacings giving computers "image" of the lifted sections and allowing a visual quality check on their fairness.

This illustrated in fig. 6. The upper sketch being the initial curve of the lifted offsets drawn by an on-line plotter.

The discontinuity, found in the area of intersection between the bilge and the flat of bottom is due to insufficient input waterlines to give precise definition in that area. Additional waterlines were added and the result is shown in the lower diagram with the area now fairly accurately defined.

With the offset generated in, manual calculations, prior to modern computer computations, this same discontinuity could well have occurred resulting in a higher displacement figure than was actually the case. This in turn would result in too high a lightship weight at the draught obtained from the inclining experiment, making it impossible to reconcile the result with the weight obtained from the detailed weight estimate.

It is therefore, considered that computer calculations, well performed, are a safeguard against such discrepancies.

To sum up: A desirable feature of a good ship computer programme is simple, easily understandable data forms with the minimum amount of input possible.

2. Flexibility of data forms and programmes, to accommodate modifications and unorthodox ship hull forms.

Hull forms, until about 10 years ago, had only small deviations from the orthodox, but now it is not unusual to incorporate, bulbous bows, bow thruster openings etc., and also it is necessary to be able to accommodate non ship-shape forms, for instance, oil drilling platforms require stability investigations to be performed.

Computations are also required for modifying or rebuilding existing hulls, such as jumboizing or lengthening ships. Extensive design computations are also essential to investigate the effects on stability of variations in beam or superstructure length. The above variations in hull forms require that the data forms can easily accommodate the additional data. The lengthening of a vessel, by the insertion of parallel middlebody can be accommodated by by adding two station spaces, equivalent to the length of the additional middlebody.

For jumboizing, either additional waterlines may be added, or a new extended superstructure might be accounted for as a "boxform" appendage volume as in the DSRI[x] programme.

Relatively few ship computer programmes consider appendages. Some define them by a volume concentrated at a point, by a sphere or compensate the appendage by the introduction of a "boxform" (6). The position of the sphere is defined by its centre of gravity co-ordinates.

The boxform compensation is considered to be more suitable because it provides not only for position and volume, but also for waterline area and moment of inertia.

In addition, the sphere gives discontinuities in the iteration process when finding the isocarene condition in the stability calculation, due to the error induced in the change of heeled volume when compared with the tolerances acceptable during the iterative procedure.

With appendages compensated for by a "boxform", as used at DSRI (6), a negative volume may also be considered so that a deducted volume, corresponding to a bowthruster tunnel for example can be incorporated.

The maximum number of appendage volumes normally applied by DSRI is 24, although this may be extended to 60 for the definition of floating drilling platforms. These platforms often consist of torpedo shaped buoyancy chambers which are submerged at the drilling site. These horizontal torpedoes are then inter-connected by circular, vertical pillars which support the working platforms, drilling tower, workshops, accommodation and heliport. By the substitution of "boxform" appendages for the pillars and torpedoes all the form-stability properties can be calculated.

A good example of the flexibility of a programme is that for the calculation of capacity, sounding and ullage tables.

This programme was offered in its basic form as an interpolation programme only, which required certain pre-calculated volume figures to establish the sounding tables - disregarding trim and its effects. At DSRI the original programme calculated the volume when full and a number of other volumes between empty and full. The sounding tables were then obtained by interpolation.
The above method is still that most commonly used, but at DSRI, the programme has been developed and augmented and now gives the following items as output.
The sounding volumes are computed directly for any arbitrary trim and/or heel value.
The complete programme not only prints out the full volume, the centre of gravity co-ordinates and the moment of inertia, but also the bale volume and five other values just below the value when tank is completely full to ensure that the maximum value of the moment of inertia is found.
The headings of the pages giving trim values, units of volumes and soundings, may be printed to the customers requirements and in any of nine principal languages.
The input data caters for a wide variation of shapes, for instance, sea valve chests, circular pillars and even allows for the thickness of the insulation inside the frames to obtain the correct hold volume in reefer ships. Transverse and longitudinal bulkheads and recesses may be defined with slope in any direction and sounding pipes can be accommodated with bends in all three planes.
The programme input may be easily transferred to investigate grain stability.
A recent example of the use and flexibility of computer programme techniques is the fairing of a ship's lines on a large scale. The fairing procedure used by DSRI and described in (8), is the only known programme that fairs the lines by describing the hull in all three dimensions by a number of mathematical polynomia without requiring specific frames or sections. This has the effect of reducing the number of offset input figures required to describe the hull from about 800 - 1000 to about 150 - 300 figures for both fore and after body.
Originally the hull was subdivided into only a fore and after body at midships, but experience during the first six months of running the programme commercially has shown that it is extremely difficult to fit a polynomial to areas of reflex curvature as found in the after body. The programme was therefore modified, within a month, so that the vessel may be split up into 3 or more regions described by polynomia. The fore-body can frequently be described by one single polynomial.
The programme initially allowed for 2 knuckle lines (chines) but it was found desirable to increase this number to 5.
A final example is when considering the bottom region of a vessel with a variable rise of floor. Originally the programme was designed to handle only constant rise of floor throughout the vessel. On one occasion, a vessel that required fairing had variable rise of floor, but the programme was easily adjusted to accommodate this and the fairing carried out without undue delay.

3. Results presented for direct use.

The way in which results from the computer ouput and/or a computer centre is presented, is of great importance in evaluating the quality of the service.
Groups and columns of figures without text is the simplest way to present output, but the location of the figures must correspond to the given explanation of the output sheet.
This method cannot be varied easily to suit the customers specific needs and is only really suitable if the results are to be used internally and immediately by persons familiar with the results.
It is more convenient, however, if the sheets are printed out simultaneously with column headings as shown in slides 11,12 and 13.
Often results of theoretic ship computations are to be used in documents or tabulations in a permanent form or for several users, the text and headings should then be arranged to suit the requirements of the owners, authorities or yards.
Programmes should therefore be designed in their initial stages to give various headings and columns so that unnecessary misunderstanding of the results can be avoided.
The DSRI capacity, sounding and ullage tables, as mentioned in the previous chapter, are a good example of the flexibility of output to suit the individual customers requirements.

Plotters governed directly by the computer or via special governors controlled by magnetic or punched tape have opened up the possibility of avoiding the manual transition of tabulations into curves and thus avoid the possibility of human error.
Often, the output from one computer has to be used as input for another, e.g., the output of a technical calculation from one centre used as input for administrative programmes at another or for other smaller specialized programmes. The results in these cases should be transmitted in a given code, or directly over a telephone or teleprinter.
The above shows that large variations exist in the ways in which results can be delivered by a computer centre so that the results can be used directly and in the most suitable way by the customer. The customer should pay strict attention to the way in which the results are presented.

4. Internal checks and compilation of data.

Generally the running of programmes on a computer is rather expensive, and it is necessary to ensure that: 1) the input data is correct, 2) the computer has read the input data correctly, 3) that progressive computations are running correctly and that probable errors are detected early to avoid any undue wastage of computer time.
The best check of the input data is to reprint it as output. All half-breadths offsets that have been used to define hull shape are reprinted in some DNV programmes, (5).
At DSRI (6), for some programmes a check of the half-breadth offsets is made by summing all the station half-breadth figures. The sum of the computer generated figures is checked against a sum manually performed at the bottom of the appropriate columns, and any differences are printed out as an error indication. Thus, it is clear whether the computer has read all the offsets correctly and simultaneously whether the half-breadths have been lifted accurately.
The above checking is supplemented by visual inspection of a drawing made by a computer-directed plotter. This drawing, fig. 14, represents the lifted half-breadth offsets on each station which are connected by parabolae between pairs of equidistant waterlines.
In programmes using a large amount of special data, such as the capacity, sounding or fairing programmes, a special test should be arranged which compares the quantities of corresponding dimension figures to check whether data has been correctly filled in.
The programmes at the Technical University of Hanover (9) check the input by a system of checks for fairness of the frames and any discontinuities recorded.
At DSRI, the computation which is based on the result of a fairing procedure need less checking. The offset data tape is first made from faired results from a reasonably faired vessel, and checking is accordingly reduced.
Another method of reducing errors due to manual lifting of the data, is to use a machine for lifting co-ordinates from body plans and transfer the figures onto a magnetic tape. Further handling of the lifted data can then be done in the programme.
During the fairing process, it is mandatory, that frequent checks and print-outs of intermediate results are made.
Another check of the quality of the faired surfaces is from visual inspection of the sections on 10 or 20 stations drawn by a computer-controlled plotter. This is shown in fig. 16 for surface in the area of a bulbous bow.
It will be appreciated that a full fairing procedure computed in one week is a very fast procedure. The schedule at DSRI is generally as follows: lifting and scaling offset data from the customers lines on a scale between 1/10th to 1/50th depending on the size of the vessel, during the weekend. Monday and Tuesday, fairing of two dimensional projected curves, which describe the transition of the polynomial surfaces of the stem, midships, bilge and other areas. Wednesday and Thursday, fairing of the polynomial regions is performed which finally results in a "ship definition tape" containing a full description of the hull by means of coefficients etc., of three dimensional surface polynomial expressions, and of the two dimensional transition curves already mentioned. This tape is then used on Friday to print the mould loft book and produce the control tape for the plotting of 1/10th scale optical marking drawings etc.
To sum up, to save expensive computer time and to achieve correct output, it is important that effective use is made of small test programmes to ensure that running time is reduced to the essential minimum.

5. Accuracy of results.

Since manual calculations for ships are now more or less superseded by computer calculations, the standard of accuracy of the results has improved. This must be true, if only from the fact that the offsets are lifted generally from about 30-40 stations and 30-70 waterlines, and corresponds to considerably more and closer spaced ordinates, than in hand calculation.
It must be admitted that there are many inaccuracies in the construction of a ship, such as welding distortion, which leads us to ask "issuch a high degree of accuracy necessary".
The real point is that the achievement of a high degree of accuracy should be the goal of each and every step in the field of ship calculation and production.
The accuracies or standard errors of computer results has been described by Mr. E. Kantorowitz (11) and (12). The errors in the results are due to the following:

1) The error, R, due to the use of Simpson's formula, is the inherent error in approximating ship curves to parabolae.
2) The end-point error, E, due to the waterlines ending in points which do not coincide with the values derived from the use of Simpson's formula.
3) Error due to measuring inaccuracies in the half-breadths, M, which may be reasonably approximated by 2,4 $^{0}/_{00}$ of the half-breadth of the vessel.
4) The error due to rounding off of figures may be neglected as the computer uses 9 significant digits.

The ultimate standard error is thus expressed as:

$$U = \sqrt{R^2 + E^2 + M^2}$$

Applying this formula the following standard errors are found:

Vessel 1. 31 waterlines and 29 stations measured.
Vessel 2. 21 waterlines and 17 stations measured.

Relative error in %

	Displacement	LCB relative to L/2.	WL area	Damage stability GMo required (% of KM)
Vessel 1:	0.04	0.04	0.08	0.13
Vessel 2:	0.14	0.18	0.16	0.26

These figures show that a much greater accuracy is achieved if 31 waterlines and 31 stations are used to define a vessel instead of the 21 waterlines and 17 stations normally used in hand calculations.
It is perhaps interesting to note that vessel on a building berth 150 m length (500 ft.) and heated on one side by sunlight to 20° C above the temperature of the other side will be distorted about 0.036m or 0.24 $^{0}/_{000}$ on one side relative to the other, which is of a magnitude greater than the standard computation errors. At temperature differences between the Mediterranean and Northern European Seas of 25°C, the volumetric difference for 150 m length vessel are of the magnitude of 1 $^{0}/_{000}$.
On a 100,000 tons tanker of about 900 ft. in length the temperature differential in a building dock has in some cases resulted in a ½ inch lift of its ends and the sun/shadow differential has caused 6 inch deflection horizontally.
Such inaccuracies in the building of the vessel show that a standard error in calculations equivalent to vessel 1 is sufficient.
For the DSRI fairing procedure, the full scale deviations may have a maximum error of 3-4 cm (1.2 - 1.6 inches) from the half-breadth given input from a reasonably well-prepared lines drawing on scales of 1/50 - 1/100th used (8). Considering that this includes the fairing of the lines and the measuring errors from the input lines-plan, the above deviations may be considered satisfactory. It is also worth noting that reading errors from drawings are 1-2 cm (0.4 - 0.8 inches) almost the same as that anticipated from the fairing process.
The mould loft book is a print of the faired waterline half-breadths to the nearest mm (0.04 inch). Iterations to find, for example, buttocks and diagonals produce offsets to ½ mm (0.02 inch).

For damage stability a number of equilibrium equations (13) govern the iteration procedure. The tolerances for the weight balance in these iterations is $\frac{Vo}{8000} m^3$ which gives a tolerance of the magnitude of 1/8 ‰.

To sum up, in order to prepare a computer programme to produce good results, it is necessary to carefully assess the accuracy to which the results are required and take the necessary steps to ensure that output accuracy. The contemporary trend to higher precision in the production of ships' units and sections also increases the requirement of the analysis of possible errors.

6. Easy checking of results.

It is not only for the sake of the Authorities and customers who will check the computation results, but also it is essential for the computer centre itself, that the output should contain features which facilitate a check on the results.

7. The packaging of computer results.

The development of single programmes to solve theoretical ship problems is of course of great importance but the full benefit of them is more effective when several ship calculations are simultaneously calculated on block or as a package. To solve one problem only, it is mandatory to scale off the offsets of the vessel in order to define the hull shape for the calculations. To perform another hull calculation at another centre would necessitate the rescaling and compilation of the data with an additional outlay of both time and money. Therefore it is of considerable advantage to perform ship computations as packages where, for a number of computations, it is only necessary to lift the data once. When a shipyard requests the hull fairing procedure, the output is in the form of a punched tape that completely defines the hull and from this a second tape which represents the hull for all the other calculations is easily derived, thus saving much time in subsequent calculations.
The above features have been worked into full scale package offers by some computer centres to include almost all ship calculations lined to the identity of the hull shape (8), (19). Computation "package deliveries" can of course include some further investigations on specific problems.
Examples are basic designs for new vessels where the lines are investigated in respect to ship stability, and a full report presented from which the regulatory authorities may directly ascertain whether the proposed vessel will comply with the existing regulations.
Another example may be an investigation required for a large passenger liner, with respect to floodable length and damage stability, resulting in a full report covering all aspects of the vessel's symmetrical or unsymmetrical flood, during the entire period of flooding.
To sum up, it is of advantage both to the user who is relieved of the detail work for a specific computation and also to the computer centre, which obtains a more complete view of the whole problem, to deliver the results as a full report.

The full DSRI package list is given in fig. 20.

FIG. 20

Review of DSRI Computer Calculations.

Fairing of vessels lines
Mould loft book preparation (9 languages)
ESSI or TELEX code tape preparation for plotter
Drawings of faired bodyplan, stem, stern and waterline (scale 1/10 or others).
Plate expansion results as tabulations or plotter expanded drawings
Hydrostatic curves and drawing, 6 alternative results available
Stability curves and drawing, still water, waves, deckedge submergence printed, constant trim or trimmoment, i.e. 5 alternatives
Heeling experiment analysis
Trim and stability booklet - loading conditions
Grain stability

Trimdiagram and drawing, 6 alternatives based on draught mark readings or draught and trim
Capacity
Sounding calibration tables, any alternative representation
Ullage calibration tables, any alternative representation
Floodable length and drawing
Damage stability and drawing, 6 alternatives
Cross-flooding equipment
Longitudinal strength, 3 alternatives
Launching
Shaft alignment
Portal frames

8. Collaboration and interaction between the computer centre and the customer.

In previous chapters, especially 1, 2 and 3, it has been already shown that a good programme cannot be developed by a computer centre alone but only as the result of close co-operation between the programmers and the customer.
It is worth noting that those who fill in the data forms are not always the same persons as those who will use the results. The educational background of those who programme is a subject for much debate. The optimum, and unattainable, is a mathematician, with a thorough tuition in systems analysis and computer programming and with an intimate knowledge of the professions of shipbuilding and ship design, including a knowledge of the technical terms and expressions used in these professions. Programmers need to discuss the problems in detail with shipyard personel to clarify specific important points to generate good data processing programmes but which are often taken as granted in the manual calculations.
A satisfactory solution is that the programmers should work in groups with professional shipbuilders and/or designers who have undergone a short preparatory course in computer techniques and their combined effort should be sufficient to solve most of the possible problems.
From experience at DSRI, it is considered that shipbuilders are an indispensable part of this collaboration, unless the individual computer specialists have shown outstanding ability in c ompletely absorbing ship calculation techniques and have been able to develop programmes that are both useful and practical. As an example, a great number of very sophisticated scientific solutions of ship fairing problems exist which are not, and never will be, used commercially, because the contact with the shipbuilder and his techniques was lacking in the development stages.
It is also very helpful if a computer centre can have a "service" staff, so that when a new programme is being developed the computer staff can readily use the "customer contact" and also that the service staff should check that the input and output of new programmes will be suitable for commercial use. Such personel may also be used to compile and obtain the necessary data for existing programmes.
The service staff should co-operate closely with Naval Architects and their staffs so that close communication maybe maintained with owners and shipbuilders at all times.
Summing up, the philosophy currently accepted by practically all who use electronic data processing it is considered that the professional staff from the practical field that are released from mundane computations by computerization must collaborate fully and directly with the programmers and in the programmes to make the new system work effectively.

9. Programmer-computer interaction and team-work.

As the main object when establishing programmes is to facilitate their commercial use, the initial stage in the programme development procedure should be to prepare input data froms and the layout of results.
The next step, is to review the main issues to be computed and as many sub-programmes, available from other programmes, should be incorporated as is feasible and that new sub-programmes should be developed with an eye to their future incorporation into other programmes.
The sub-programmes are essential for the standardization and streamlining of programming work.

It should be emphasized that some shipbuilding programmes, that for fairing for instance, are so complex that they may take many years to establish. The effort being so great requires that a large amount of planning and thought should be directed into developing the programme.
It is quite normal that one third of the programme will be taken up just for reading and testing the data. Sub-routines, as part of the total programme, are sections that have been thoroughly tested and may beconfidently incorporated into other programmes, thus saving manpower and time.
A typical sub-routine need in the hydrostatics and stability field at DSRI, is the calculation of area, moment of area, and waterline half-breadth of an arbitrary submerged portion of a frame.
A similar sub-routine is that which calculates the same properties for a compensating "boxform" appendage.
These sub-routines areused in numerous programmes among them the following: Righting arm curves, inclining experiment analysis, damage stability, hydrostatic curves, bonjean tables, trim tables and launching calculations.
The mathematical fairing procedure which defines the hull by three-dimensional polynomial surface coefficients is called "ship definition" and is used as a "Sub Routine" in other programmes such as:
Mould loft book, plotting ESSI and shell expansion programmes and for generating offsets for other programmes.
In all programmes, a series of sub-routines, such as "Read in Ship Definition" is used. This procedure can define arbitrary points on contour curves and intersections between curves, e.g. the stem and sheer curve.
A large part of the total computer programme time and content is need performing these various sub-routines, therefore any effort to increase the effectiveness or efficiency of such routines is amply rewarded.
For new staff also it is much easier to become familiar with programmes if the sub-routines are well established.
Group and team work are essential to the preparation of new programmes and provided that every member of the group is familiar with construction of the total programmes or sub-routines the following advantages are apparent:

1. No difficult situations develop if a staff member changes his job
2. The "breaking in" of a new man can be shared among more personnel
3. It is easier to resolve programming difficulties by discussion as a group
4. It is less probable that effort and time will be wasted in "dead end" work.

Some disadvantages in team work are that it requires, close planning, the goodwill and co-operation of all the staff and that certain ultra-sophisticated proposals must be simplified so that the whole staff can absorb and understand them.
The internal structure of a programme is normally determined by the size and configuration of the computer that is used.
The size of a computer is often defined by its capacity given as a K value in units of 1000 words (orders) or 1000 figures with 8 - 10 decimal digits.
A 32 K computer may have a core store capacity of 32,000 words in the store where the arithmetic process takes place. Combined with core store or auxiliary stores are drums, magnetic tapes, and/or disc files having a much larger capacity, but requiring the transport of the stored programmes and data to the core store for processing. Lastly, data may be stored on paper tape or punched cards, Both have unlimited storage capacity but very long access time.
It is possible to prepare any ship computation for any computer. If the store capacity is larger, the programming effort and computation time are generally reduced. Storage capacity can be so small that computer time becomes excessive and uneconomical.
Solutions of the ship problems normally considered can be handled by computers with a core capacity greater than 1 K, and a supplementary storage capacity of 100 K or 2 - 4 magnetic tape stations.
Generally it is advantageous to have separate computers for technical or administrative computations.

The problem of fairing vessels lines has been solved on greatly differing computers, at DSRI with a core store of 1 K and approximately 38 K drumstore and at other computer centres with up to 24 K core and 400 K drum store and 4 magnetic tape stations.

10. The importance of a large turn over in the use of commercial programmes.

When the first computer programmes were developed it was a rather widespread belief that once a programme was satisfactorily developed and established that it would remain unaltered and give good results for several years, requiring no further effort to maintain the programme. After some twenty years, since the initial inception of computer programming, experience has shown a very different situation.

First of all it is manifest, especially for the more complex programmes, that very considerable time is used during the initial test stages. Later, a number of modifications and additions must be made to the programme as it is used more frequently for commercial runs.

In the full text of the paper presented by Mr. Johannsen, several examples are given of the necessity of frequent modification and addition to programmes to satisfy unusual ship forms, the requirements of Classification Societies and Maritime Authorities and the general progress of the Shipbuilding Industry.

Conclusion.

Good ship computer programmes clearly state the measurements and data used in the computation and should be easily readable and usable and should be based on a detailed definition of the hull.

Complex programmes should have a large turn-over to eradicate all possible sources of error in all cases and to ensure a short delivery time.

Acknowledgement.

The writer of this precis wishes to express his appreciation to Mr. Ulrich Johannsen, author of the original paper, for his invaluable assistance and his generosity in offering to participate in the written discussion.

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14)	C.W. Prohaska	Influence of ship form on transverse stability	INA transact. Oct., 1951.
15)	C.W. Prohaska	Residuary stability	INA transact. 1947.
16)	G.R. Dicovi	Damage stability calculations by Electronic computer	Danish Ship Research Institute Rep. DSF-13
17)	S. Velschou	Longitudinal strength by computer	Shipp. World & Shipb. July, 1966.
18)	Sentralinstitut for Industriel	Fairing procedure	
19)	Danish Ship Research Institute	Review of programmes	April, 1968.

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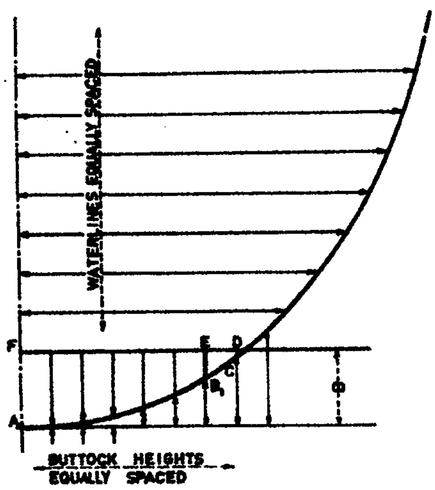


FIG1

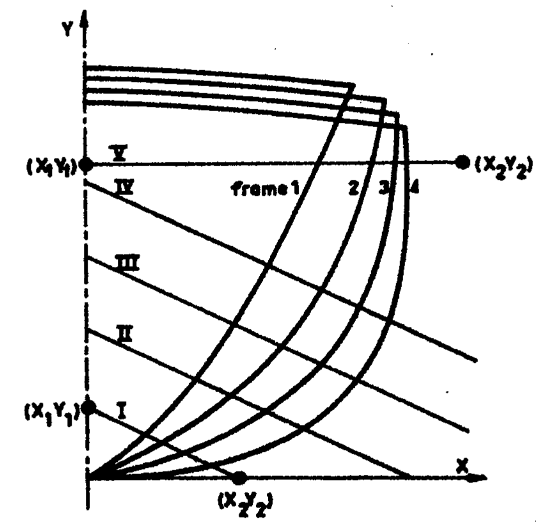
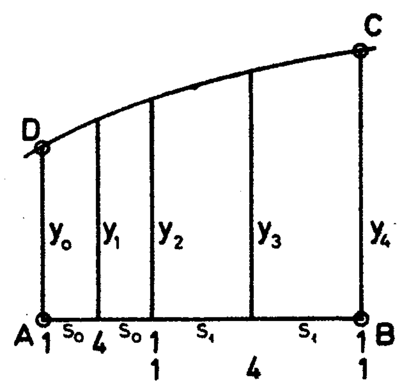


FIG 2



Area ABCD =

$$\tfrac{1}{3} S_0 \,(1\,y_0 + 4\,y_1 + 1\,y_2) \; + \\ \tfrac{1}{3} S_1 \,(1\,y_2 + 4\,y_3 + 1\,y_4)$$

FIG 5

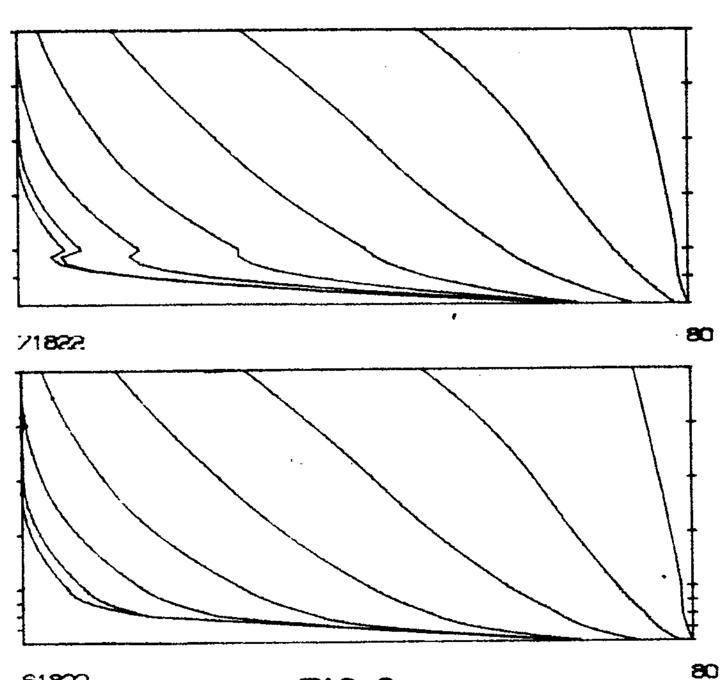


FIG 6

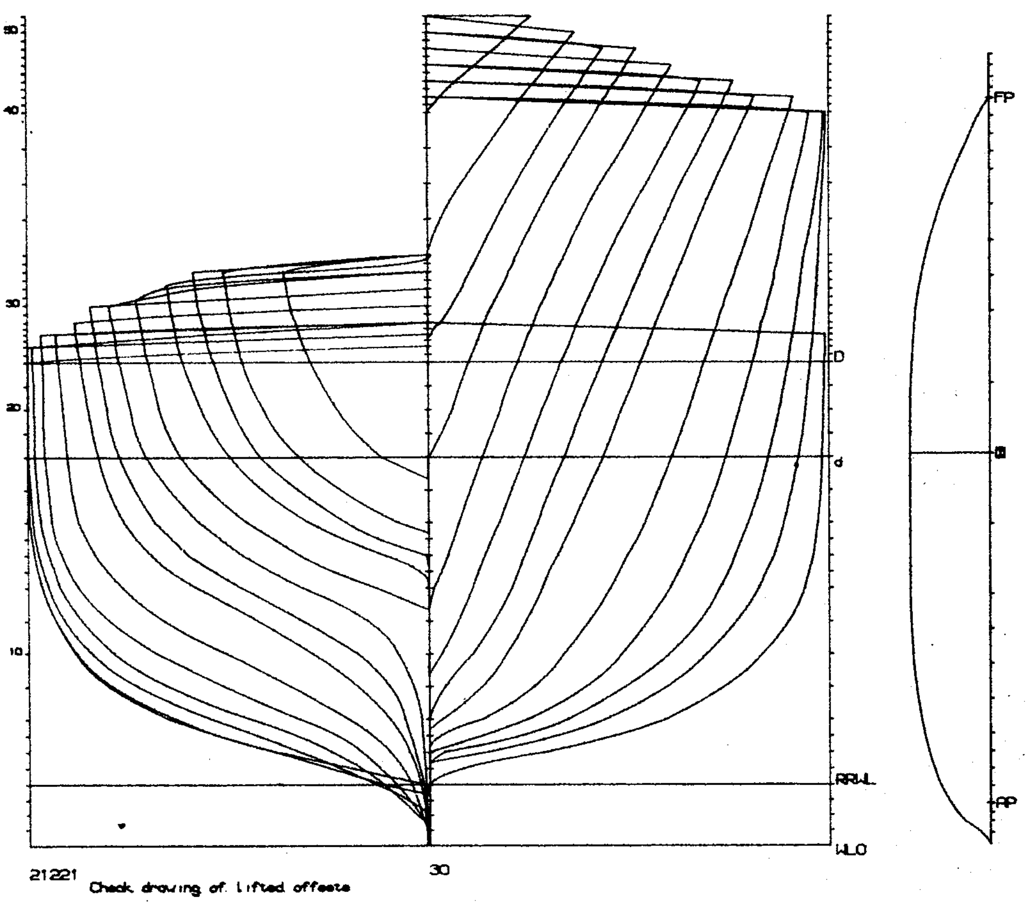

50
40
30
20
10
D
d
RRWL
WLO
FP
B
AP
21221
Check drawing of lifted offsets
30

FIG.14

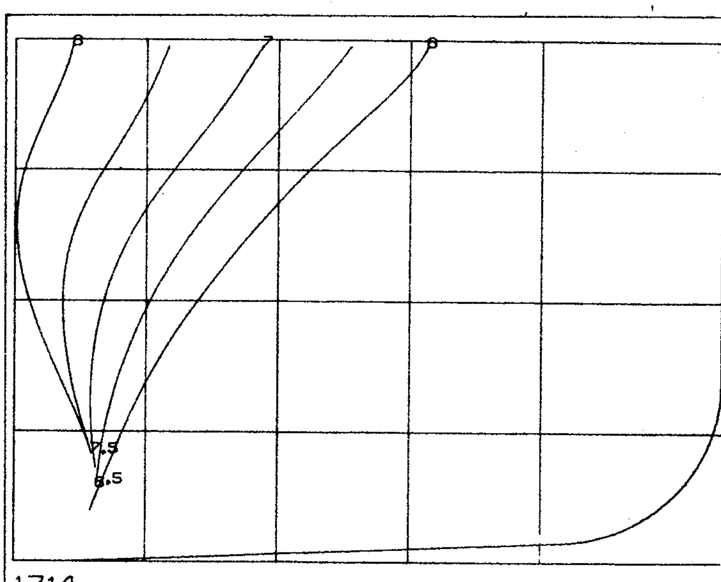
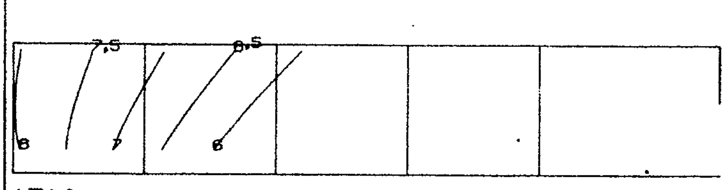

8
7
6
7.5
8.5
1714 16

FIG 16


7.5
8.5
8
7
6
1714 14