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The suitability of radar simulators in marine casualty investigations / by Federico Hatzenbühler.

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THE SUITABILITY OF RADAR SIMULATORS IN MARINE CASUALTY INVESTIGATIONS

by

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The contents of this Paper reflect my own personal views and are not necessarily endorsed by the UNIVERSITY.

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PREFACE

During the more than two years of work as an instructor in the radar simulator of the Argentine Merchant Marine Academy, I became increasingly aware of the wide training applications of this type of simulators. My interest also extended to the possible use of radar simulators in the field of marine casualty investigations. By a fortunate coincidence, while these thoughts came to my mind, I was selected by the authorities of my country to take the course on Maritime Education and Training (Nautical Field) in the World Maritime University, which I consider fortunate because it gave me the opportunity to continue the analysis of that particular subject fulfilling at the same time part of the requirements of the Institution for the award of the M.Sc. degree.

I have developed this project conscious that I am not a pioneer in the field. Radar simulators have been used by a number of very experienced professionals to carry out the investigation of marine casualties. In this thesis I intend to make an objective analysis of the subject considering the different contributing elements, in an attempt to draw conclusions and provide gidelines which might be of help to all those who in one way or another are involved, or may become involved, in marine casualty investigation procedures.

Many people have contributed to making this thesis possible and it would be almost impossible to name them all. They assisted me in getting a better understanding of the subject and to carry out the research work. I am particularly indebted to Bo Högbom for the time he has willingly given and to Johan A. Klerk for his great encouragement and critical analysis of the project. Also, my gratitude to Johan Van Walen for his patient revision of the manuscript and valuable comments.

F. Hatzenbühler

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CHAPTER 1

INTRODUCTION

1.1 Aim of the project

This study deals with one of the negative results of human activity which is marine accident occurrence, and the consequent investigation.

Accepting the fact that despite all efforts, marine casualties still continue to occur, the aim of the project is to contribute to the reduction of accident frequency, specifically collisions at sea. A thorough analysis of the events which led to such a casualty and their causes, can enable maritime administrators to take measures which may prevent the repetition of the occurrence. In many cases, however, the first obstacle to this approach is the difficulty to ascertain the course of events. This is especially the case when the investigation process is hampered by lack of evidence and/or contradictory statements.

Technological developments in recent years have introduced a radical change in the maritime industry which has also resulted in improved training facilities. Radar simulators in particular are nowadays found in a great number of maritime education and training institutes as well as in research centers. Such highly advanced training tools can be used in many applications and one in particular is analyzed in this project, that is the investigation of collisions at sea.

1.2 General definitions

So far, the terms "accident" and "casualty" have been used. Let us investigate into the terminology in order to clarify the meaning of those words. A dictionary will give the following definitions of "accident":

> "Sudden event or change occurring without intent or volition through carelessness, unawareness, ignorance or a combination of causes and producing an unfortunate result"

or

> "An unintentional act, chance, misfortune, especially one causing injury or damage"

and for "casualty" :

> "A person or thing that has failed, been injured or lost or destroyed as a result of uncontrol - lable circumstance or of some action"

From these definitions it can be concluded that both terms are suitable to describe an occurrence characterized by two important features:

(a) loss of control

(b) unfortunate consequences

Strictly speaking, however, the definition of casualty refers more to the person injured or the thing damaged, while accident is always the event itself.

If we look into the wording used in different English speaking countries, it will be found that there is no common terminology and both terms are used with the same meaning. Certain authors prefer to define "casualty" as an occurrence which results in damage to property, while "accident" involves injury or death of people. In IMO the word casualty is used, whatsoever the consecuences of the occurrence are. Therefore, for the purpose of this study both words will be accepted as synonyms and used as such.

The unfortunate results which form part of any accident, leave out of the definition those occurrences which could have, but did not, resulted in a casualty. Those cases will be referred to as "incidents", defined in a dictionary as :

"A disturbance or other action likely to lead to grave consequences"

Incidents and accidents are occurrences which happen in any field of activities. A marine occurrence is defined as an incident or an accident related to the use or operation of a ship. This is a very broad definition, and many countries have included in their legislation a clear specification of the cases which are considered marine occurrences. In this way, a clear jurisdiction is provided to the authorities who have to deal with those cases.

In this study, collisions at sea as well as groundings will be dealt with, and according to any definition, it is clear that they are special cases of marine accidents.

1.3 Why do accidents happen ?

It seems quite obvious that an accident occurs because something went wrong. But it is not so easy to specify what went wrong. All the publications dealing with this problem arrive at the conclusion that human error is the principal cause of accidents, and that is true in essence. It might be argued, however, that in its broadest sense, any accident is due to human failure. People have been involved either in the design, construction, inspection, maintenance, repair or operation of any device or mechanism used. Therefore, when considering the human factor as cause of accidents, two important points must be considered :

(a) human factor has to be taken in its collective meaning
(b) human failure has its causes

On the other hand, it is also important to study human behaviour because this will help to understand the reasons for people doing things wrong.

In certain cases there is an escape-way by attributing the cause of an accident to an "act of god" but even this can lead to endless discussions. It is certainly possible to attribute almost all accidents to human error, but a better approach would be to use more precise terms to describe the cause of an accident, such as :

(a) Environmental accion
(b) Technical failures
(c) Errors in design
(d) Internal or external communication problems
(e) Organization problems
(f) Lack of regulations
(g) Non-compliance with regulations
(h) Poor training
(i) Lack of information
(j) Misinterpretation or incomplete utilization of information
(k) Misjudgement
(l) Error
(m) Negligence
(n) Stress

1.4 Is it possible to reduce the accident frequency ?

From a very pessimistic approach, it might be said that accidents are part of daily life and nothing can be done to avoid them. Then, with a good background in mathematics, it is enough to forecast statistically the number of casualties and later check the accuracy of those predictions, mainly for the benefit of mathematicians, insurance companies, etc. Fortunately, however, there is a different approach to the problem, as many people think that something can be done in order to reduce the accident frequency. A large number of statistics also show that a lower accident frequency has been achieved after adequate preventive measures have been taken. This in fact means that if the frequency dropped, a number of casualties have been avoided.

1.5 How can accidents be avoided ?

In order to decrease the casualty frequency, it is necessary to reduce or eliminate the causes of casualties or "safety hazards". The expression "safety hazard" can be defined as a situation or condition that could, if left unattended, induce an incident or accident.

The best way of eliminating accidents would be to detect all safety hazards before putting anything into operation or establishing any procedure, and thus achieve 100 % safety. It can easily be understood that it is almost impossible to arrive at this solution , as there will always be a margin of uncertainty in the operation of any system which is beyond the control of the designer. On the other hand, the economic factor plays an important role when the reduction of safety hazards implies an important increase of costs. Nevertheless, there are examples of activities where safety is given a very high priority. In air traffic, for instance, impressive efforts have been made to reduce safety hazards to a minimum, and the success can be measured through the very low accident rate. This can be attributed to the nature of that particular means of transport, in which the elimination of accidents is a key to profitable business.

A second way to reduce safety hazards is by learning from experience, after an accident actually occurred. By this we are again accepting that casualties will continue to occur and unfortunately there are strong reasons to believe that this is true. But it must be remembered that the objective is to reduce the rate of occurrences.

Whenever an accident occurs, and depending on the dramatism and consequences of the event, a natural reaction will be that a number of questions arises .They will include when, where, why, how and who. The reasons for asking these questions vary according to the interests of the people concerned. The media have to provide as many details as possible, especially those that produce greater impact in the public. The general public will be interested for reasons of curiosity. In case of injuries or death, relatives will be specially concerned. Those who are financially involved, or may suffer any consecuence, will be particularly interested. Last but not least the authorities who have to deal with the occurrence will certainly intervene and take the necessary steps to try to clarify the situation.

By this approach, and as it has often been demonstrated in practice, accidents must occur before safety measures are taken. The maritime field is not an exception to this rule, as a few examples can show :

(a) An amazingly large number of overloaded British ships had to sink before Samuel Plimsoll could convince the British Parliament to issue in 1876 the Merchant Shipping Act requiring to mark the deck line and the permissible draft. As a matter of fact Plimsoll gave public and parliamentary expression to the information provided by James Hall, a ship owner who had fought continuously for load line legislation from 1869 onwards. Legislation on this matter can be traced as early as 1288 in the Hanseatic Leage. The British Act of 1876 didn't even specify where the so called Plimsoll mark should be. Still 54 years had to pass before the first International Load Line Conference was held, in 1930, in order to set internationally agreed standards.

(b) The British passenger liner "Titanic" sank on April 15, 1912, during her maiden voyage, after stricking an iceberg about 95 miles south of the Grand Banks of Newfoundland. The vessel had been considered unsinkable, but did sink, however, with a loss of more than 1500 lives. The liner "Californian", stopped less than 20 miles away, could have aided to salve many lives, had her radio operator been on duty. As a result of the accident, safety measures were sped up and the first International Convention for Safety of Life at Sea was called in London in 1913. The Convention drew up rules requiring that every ship have lifeboat space for each person embarked. The Titanic had only 1178 boat spaces for the 2224 persons aboard. The Convention also required that lifeboat drills be held during each voyage, and a 24-hour radio watch. This Convention never entered into force due to the out-break of World War I, but was the base for future SOLAS Conventions.The International Ice Patrol was also established to warn ships of icebergs on the North Atlantic routes.

(c) The "Morro Castle", a passenger ship with accommodation for 490 passengers, caught fire during the last part of her journey from Havana to New York on september 8, 1934. The vessel was carrying 316 passengers and 232 crew members, and as a result of the tragedy, 124 people lost their lives. The luxurious vessel was constructed with large quantities of highly combustible linings and furnishings in all accommodations. These characteristics, together with the lack of training and organization of the crew, contributed to the rapid spread out of the fire, which became uncontrollable in a short time and led to the tragic consequences mentioned. After this casualty, substantial changes were introduced in the U.S. legislation in order to improve safety standards on board ships.

(d) Collisions occurring in converging areas and in areas where the density of traffic is high, resulted in suggestions for the adoption of some kind of separation. The first recommended routeing scheme was established for the Dover Strait in 1967 and many others followed. The International Regulations for the Prevention of Collisions at Sea include the rules applicable to vessels using Traffic Separation Schemes adopted by IMO. Those rules do not represent a guarantee of absolute safety and as a matter of fact it is discussed whether their application might result, in certain circumstances, in a greater risk. Amendments will probably introduced in the future. Nevertheless, the adoption of regulations concerning routeing schemes represent a major step forward in the prevention of marine occurrences.

(e) On March 18, 1967, the "Torrey Canyon", a super-tanker fully loaded with more than 100,000 tons of crude oil, ran aground on the Seven Stones rocks off the British coast. The south-west coasts of England and northern coasts of France where menaced by the oil spillage. Long before, pollution experts had been concerned with the possible consequences of the increasingly larger tankers running aground or colliding. The Torrey Canyon stranding put the world face to face with a massive marine pollution resulting from a shipping casualty. It showed that such accidents can have serious effects upon the environment and marine life, damaging resources such as fisheries and tourism for long periods. The case helped to speed up the further development of international regulations for the prevention of marine pollution as well as provisions related to pollution damage liability and compensation.In this context, the International Convention Relating to Interventions on the High Seas in Cases of Oil Pollution, adopted in 1969 , can be mentioned. In addition, four international compensation schemes were developed during the post-Torrey Canyon period, which are known as CLC 1969, TOVALOP 1969, FUND 1971 and CRISTAL 1971.

1.6 Conclusion

As it has been mentioned, after an accident has been reported the Government authorities will take action, usually in the form of some kind of investigation. The procedures and objectives vary from country to country, according to what has been specified in each particular legislation. If enough emphasis is put on the determination of the cause or causes of the accident, then as a consequence safety measures can be taken in order to make such a casualty less likely to happen again in the future. In too many cases, the accident itself works as a catalyzer to push forward safety measures which might have been taken at an earlier stage to prevent the occurrence.

The field of accident investigation is extremely ample and covers all human activities. This study only deals with marine accident investigation, specifically cases of collision at sea and the possibility of using radar simulators as valuable tools during the investigation. A general revision of marine accident investigation is the subject of the next chapter.

CHAPTER 2

MARINE CASUALTY INVESTIGATIONS

2.1 Purposes and objectives

Marine casualty investigation (or marine accident investigation) may be defined as a procedure aimed at determining the facts, conditions and circumstances relating to a marine accident. There are two main aspects to consider. First, the immediate reasons for carrying out the investigation, and second, its final objectives. The main purposes of the investigation can be stated as follows:

(a) find out facts
(b) collect all relevant information
(c) determine the most probable course of events

The objectives of the investigation differ considerably from country to country, in accordance with each particular legislation, and can vary from purely penal systems to safety promoting systems. The following main objectives can be identified:

(a) determine cause relationship
(b) recommend safety measures

(c) establish fault and take disciplinary action

(d) apportion liability

Objectives (a) and (b) are very closely linked, as effective prevention measures can only be taken when a thorough investigation of the accident is carried out establishing as accurately as possible the reasons why that particular accident happened.

It can be said that marine accident investigation is a complex of activities and that it is very much related to the traditions of each country. In some legislations very specific rules have been established, a detailed analysis of which is beyond the scope of this study. A broad description of the investigation procedure and the work of international bodies on the subject will be given, emphasizing those aspects which are important for the purpose of this project.

2.2 The investigation procedure

Regardless of the objectives, the common practice adopted in most maritime countries is a system which in many cases is divided in two stages and that will be briefly outlined.

After the marine accident has been reported and it is decided that it will be investigated, an officer is appointed by the Governmental authority concerned in order to carry out what is generally known as a preliminary investigation or preliminary inquiry. The investigating officer must proceed as soon as possible to the scene of the casualty or a convenient site, in order to gather the necessary information. His duties will include the inspection of all premises and objects which appear to be requisite for the purpose of the inquiry, the examination of all persons he thinks necessary and the collection of whatever other evidence which can be obtained, such as charts, books, papers and other documents. At the end of the inquiry, the officer will prepare a report containing a full statement of the case and his conclusions. This report may also include his recommendations for avoidance of repetition of the occurrence as well as action to be taken against licences held by persons involved. In many cases this preliminary inquiry is of confidential nature, but there is no common rule established.The findings, therefore, may be published or kept restricted. Based upon such report, sent to the appropriate Minister or other authority, it is decided whether a formal investigation should be held, which then would be the second step of the procedure. The reasons for holding a formal investigation may be of different nature including, among others, factors such as:

(a) the preliminary inquiry is not considered sufficient
(b) serious damage or loss of life occurred
(c) licences of the master, of any officer or of the pilot might be suspended or cancelled
(d) the lessons which can be learnt merit a deeper investigation

If it is decided to carry out a formal investigation, again an investigating officer or an investigating board will be appointed. Under certain legislations, this formal investigation has the character of a public inquiry. As a result of this investigation, a full report shall be produced. This report contains the description of the case,the conclusions, and the recommendations for proper action. It may include disciplinary action against the master, officers, pilot or other persons involved in the accident. Under certain legislations the report is made available to anyone and it can even be used in subsequent civil procedures.

Due to the international nature of shipping, it often happens that a flag State must conduct investigations outside its territory. Conflicts may arise when ships of different flags are involved, or when coastal States investigate casualties involving foreign flag vessels. In many cases, the accident which has to be investigated occurs within the jurisdiction of another State. The State in which the accident occurs will carry out its own investigation as it is not usual to conduct a joint inquiry. This problem has been recognized and considered at international level, as it will be analyzed further on in this chapter.

An aspect which has just been mentioned and can not be neglected in any accident, is the question of civil liability. This legal proceeding is aimed at establishing liability, generally for insurance purposes, and the parties will be all those who have suffered losses as a result of the casualty. In a collision between two vessels, for instance, it is necessary to apportion fault between the ships involved. There may be a negotiated solution to civil liability disputes, and if not, the case will be taken to court. It is found that in many countries the proceedings related to civil liability are totally separated from the inquiry conducted by the Government, although no common rule can be drawn.

The determination of the course of events prior to a collision is the main point in this study. Some characteristics of marine accident investigation which are specially important will be analyzed.

2.2.1 Composition of the investigating body

In order to conduct the official investigation of a marine accident, an investigating body has to be appointed, and its jurisdiction and competency must be clearly established in the national legislation. In those cases in which the procedure is divided into a preliminary inquiry and a formal investigation, if the latter is required, the common practice is to appoint an official to conduct the preliminary inquiry, while the formal investigation will be carried out by an investigating board or court. In any case, an investigator in charge will be responsible for the planification, organization, co-ordination, conduction and supervision of the investigation.

Marine accidents cover a wide spectre of cases and not two casualties are alike. Therefore, the size and scope of the investigation must be directly related to the nature of the accident. In certain cases, the causes of the casualty become clear at an early stage and no further inquiry is necessary. On the other hand, more than often the causes are not readily apparent. Evidence may be lost or destroyed during the accident, or even by deliberate act; witnesses may not be available, or their statements contradictory, and so forth. These cases represent sometimes a formidable challenge to the investigator in charge, and the best way to tackle the problem is to organize a team of investigators possessing the expertise relevant to the type of accident in question. This team can be divided in groups if an extensive investigation is required and those groups might be in charge of the following areas of investigation:

(a) nautical
(b) technical
(c) environment
(d) medical and human factor
(e) examination of witnesses
(f) evacuation, search and rescue, and fire fighting

It should be clear that the groups have to be established according to the type and extent of the investigation. The main purpose of such a group system is to make use of the specialized knowledge and practical experience of the participants in the investigation. These groups must collect facts, gather evidence and if necessary, conduct tests and trials. A close cooperation among groups is required, and the exchange of information may be vital for the success of the investigation. The investigator in charge is responsible for co-ordinating the work of the groups and supervising the collection of all reports in order to prepare the final composite report.

2.2.2 Examination of witnesses

The statements of witnesses constitute one of the fundamental pillars of the investigation. On the other hand, the examination represents a conflictive aspect. The question which arises is how open and spontaneous can one expect a witness to be if he knows that the evidence he should give might expose his fault or be used in one way or another against himself.

As it has been mentioned earlier, the systems vary from country to country. While certain Administrations conduct inquiries mostly to determine blame and impose penalties, others exercise no disciplinary jurisdiction at all and this matter is dealt with in a separate proceeding. From the safety point of view, a marine occurrence investigation system totally independent of any disciplinary process has certainly many advantages over any other system. On the one hand, the investigators do not have to deal with duties of safety and enforcement at the same time and on the other hand, this approach may result in a less defensive attitude of the witnesses. This is especially the case if the confidentiality of statements is guaranteed and the witnesses are told so beforehand. However, such a system should not prevent the investigators from including in their reports findings from which it may be concluded that faults have been committed and therefore disciplinary action might be taken afterwards.

2.2.3 Independence of the investigating body

Bearing in mind that one of the objectives of marine accident investigation is safety promotion, the impartiality of the investigating body is analyzed here.

In many Administrations, the same authority responsible for the maritime regulations and their enforcement, is the investigating authority in case of accidents. In those cases, it is argued that there is a potential conflict of interest. The investigator may arrive at the conclusion that there are safety deficiencies in the regulatory requirements or in their enforcement, and it can be asked whether he will be willing to criticize his colleagues or his superiors. Therefore, a tendency to minimize or even to avoid mentioning weaknesses within the organization can be expected.

Total independence of the investigating authority can obviously be never achieved as it has to find its place somewhere within the administration. However, by separating the investigating body from the authority directly responsible for the implementation of regulations, the impartiality mentioned can be better guarantied.

2.2.4 Dissemination of reports

As mentioned , a report resulting from a marine casualty investigation will usually contain recommendations if that is felt necessary in order to take safety measures. Sometimes these recommendations will lead to changes in the regulations which may well imply a long process.

Another way of taking advantage of casualty investigations, besides making recommendations, is to make the findings easily available to the people who can learn safety lessons. The publication of investigation reports is as important when human error is found to be the direct cause of the casualty as when system deficiencies are involved. Reports which are made public do not have to include names of persons involved, but should include a factual narrative of the events, an objective analysis of the evidence and findings on contributing factors and causes of the marine accident. Should the information get into the hands of seafarers, shipbuilders, shipowners, ship operators and training institutes, each of them may benefit from the lessons learnt.

2.3 Work of the International Maritime Organization in relation to the investigation of maritime accidents

IMO started its work in January 1959 after entry into force of its Convention in 1958. Prior to the amendment of the Convention in May 1982, the name of the Organization was

Inter-Governmental Maritime Consultative Organization (IMCO). In accordance with its objectives, the Organization gave attention, among other subjects, to measures and problems relating to marine casualty investigations. The principal treaty provisions on the subject are contained in the SOLAS Conventions, the 1966 International Convention on Load Lines and the International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978. The 1948 SOLAS Convention, responsibility for which was assumed by the Organization in 1959, contained a provision requiring States parties to conduct investigations into casualties. This provision has been retained in successive SOLAS Conventions. Similar provisions are contained in the International Convention on Load Lines, 1966 and in the International Convention for the Prevention of Pollution from Ships, 1973/1978. All three have been transcribed in Annex 2.1 (page 25), Annex 2.2 (page 26),and Annex 2.3 (page 27), respectively.

The matter was considered in 1961 by the Maritime Safety Committee (MSC) which arrived at the conclusion that the information available to the Organization could not be considered as providing "sufficient conclusions or guidance towards the object of the SOLAS Regulations on the subject" but it did provide some help "in establishing clues to the main and most common causes of marine casualties".

In 1967 a Legal Committee was established in the Organization and this body submitted to the Assembly a draft resolution on participation in official inquiries into marine casualties. The Torrey Canyon accident was the main factor which sped up adoption of the resolution A.173 (Annex 2.4, page 28). One of the objectives was to encourage administrations to work towards more uniform practices in the field of marine casualty investigation, particularly in case of oil pollution.

In 1975, the MSC considered a proposal regarding the implementation of the marine casualty provisions of the 1960 SOLAS and 1966 Load Lines Conventions. The proposal stated that there was a need for better feed-back to the Organization of information about casualties and "a better indication that Administrations were implementing their obligations under the Conventions to conduct investigations into casualties". As a result, resolution A.322 was adopted in November 1975. This resolution has been transcribed in Annex 2.5 (page 31). In conformity with the request, the MSC established a procedure applying to casualties involving ships of not less than 1600 grt which were a total loss and to casualties involving ships of not less than 500 grt involving loss of life. On the basis of LLoyd's Quarterly Casualty Returns and the monthly casualty lists issued by the Liverpool Underwriters Association, the Secretariat requests relevant administrations to submit reports on serious casualties to the Organization. Once a year the MSC receives a list of serious casualties upon which no reports have been received and a list containing extracts from the reports provided by the flag States. Where appropriate, casualty reports are brought to the attention of the Committee's Sub-Committees for further consideration and action. The Tanker Casualty Data Scheme is also a follow-up action. Data about tanker casualties are collected and analysed annually for further submission to the apropriate Sub-Committees.

In 1978, a Member Government pointed out that "in the case of casualties involving ships of different flag States official investigations are often hampered by the fact that some Administrations are, for legal reasons, reluctant or unable to provide detailed information to foreign Administrations". The MSC agreed on a recommendation on the subject and the Assembly adopted resolution A.440 (Annex 2.6, page 33).

It must be borne in mind that international Conventions bind legally Contracting Parties, while resolutions are only recommendations made by the Organization which may be accepted or not. Whith regard to the Conventions mentioned before, it should be noted that as at 31 March 1985, 114 States have accepted either SOLAS 1960 or SOLAS 1974 Conventions and 102 States have accepted the International Convention on Load Lines, 1966, while as at 31 December 1984, 37 States have accepted either the International Convention for the Prevention of Pollution from Ships, 1973 or the Convention as amended by the Protocol of 1878.

The matter of inquiries into marine casualties at an international level still requires considerable attention in order to solve the different problems involved and the International Maritime Organization is expected to continue dealing with the many aspects of the problem, in its role of maritime safety promotion.

2.4 Work of other international bodies

In the context of marine casualty investigation, two other international treaties include provisions on the subject:

(a) International Labour Organization (ILO) Convention No. 147, 1976, concerning minimum standards in merchant ships. This Convention entered into force in November 28, 1981 and the relevant article has been included as Annex 2.7 (page 35) in this chapter.

(b) The United Nations Convention on the Law of the Sea, 1982, which is not yet in force, includes a provision under the duties of the flag State. The article has been transcribed in Annex 2.8 (page 36).

2.5 Conclusion

The importance of marine accident investigation has been recognized and most maritime countries have set up the necessary infrastructure to conduct inquiries, although there is still a lack of harmonization at international level on the subject. In this chapter, a general description of marine accident investigation and its main features has been given. In the next chapter, radar simulators will be dealt with in order to establish a link with the accident investigation process.

Annex 2.1

INTERNATIONAL CONVENTION ON LOAD LINES, 1966

Article 23

Casualties

(1) Each Administration undertakes to conduct an investigation of any casualty occurring to ships for which it is responsible and which are subject to the provisions of the present Convention when it judges that such an investigation may assist in determining what changes in the Convention might be desirable.

(2) Each Contracting Government undertakes to supply the Organization with the pertinent information concerning the findings of such investigations. No reports or recommendations of the Organization based upon such information shall disclose the identity or nationality of the ships concerned or in any manner fix or imply responsibility upon any ship or person.

Annex 2.2

INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1974

CHAPTER I

GENERAL PROVISIONS

PART C - CASUALTIES

Regulation 21

Casualties

(a) Each Administration undertakes to conduct an investigation of any casualty occurring to any of its ships subject to the provisions of the present Convention when it judges that such an investigation may assist in determining what changes in the present Regulations might be desirable.

(b) Each Contracting Government undertakes to supply the Organization with pertinent information concerning the findings of such investigations. No reports or recommendations of the Organization based upon such information shall disclose the identity or nationality of the ships concerned or in any manner fix or imply responsibility upon any ship or person.

Annex 2.3

INTERNATIONAL CONVENTION FOR THE PREVENTION OF POLLUTION FROM SHIPS, 1973, AS AMENDED BY THE PROTOCOL OF 1978

ARTICLE 12

Casualties to ships

(1) Each Administration undertakes to conduct an investigation of any casualty occurring to any of its ships subject to the provisions of the Regulations if such casualty has produced a major deleterious effect upon the marine environment.

(2) Each Party to the Convention undertakes to supply the Organization with information concerning the findings of such investigation, when it judges that such information may assist in determining what changes in the present Convention might be desirable.

Annex 2.4

RESOLUTION A.173(ES.IV)

28 November 1968

PARTICIPATION IN OFFICIAL INQUIRIES

INTO MARITIME CASUALTIES

"The Assembly,

Noting that there is a variation in the practices of Member States with regard to official inquiries into maritime casualties, and other proceedings directly consequent upon such inquiries,

With a view to ensuring that States seriously affected by or having a substantial interest in maritime casualties, particularly where oil pollution to their coasts has resulted, shall have an opportunity of being represented at inquiries into, or other such proceedings relating to, such casualties, and

Desiring to encourage international unification of practice in relation to such inquiries and proceedings.

Recommends to governments that if a State other than the State of the flag is known to have been seriously affected by or to have a substantial interest in a maritime casualty occurring to a ship of the flag State (particularly where the coast of that other

State has been polluted by oil as a result of the casualty):

(1) (a) the State of the flag should,unless an inquiry is held by that State as a matter of course, consult with that other State as to the holding of an inquiry into the casualty by one or the other of the States, complying with the provisions of sub-paragraph (2);

(b) if such an inquiry is held as a matter of course by the flag State, the other State should be informed of its time and place;

(2) such an inquiry should be so conducted that, subject to the national rules relating to the special conditions under which inquiries are held in camera,

(a) the public is permitted to attend; and

(b) arrangements are made which would , subject to the discretion of the authority holding the inquiry, allow a representative of the other State concerned to attend and participate in the inquiry at least to the extend of:

(i) questioning witnesses or causing questions to be put through the authority concerned; and

(ii) viewing all relevant documents;

(3) if an inquiry is held by a State seriously affected or

having a substantial interest, a representative of the State of the flag should be given similar facilities.

If one or other of the conditions of sub-paragraph (2) above cannot be complied with at the inquiry itself, this recommendation shall be treated as being complied with if the condition not previously satisfied is satisfied in proceedings directly consecuent upon the inquiry. Nothing in this recommendation shall affect or apply to the holding of any preliminary or informal inquiry or any other proceedings.

A State shall not be treated for the purposes of the recommendation as being affected by or having a substantial interest in a maritime casualty by reason only that it is the flag State of one or two ships in a collision, nor should the fact that one or more of its nationals has a commercial interest in the ship or its cargo in itself confer such an interest."

Annex 2.5

RESOLUTION A.322(IX)

12 November 1975

THE CONDUCT OF INVESTIGATIONS INTO CASUALTIES

"The Assembly,

Noting Article 16(i) of the IMCO Convention concerning the functions of the Assembly,

Noting further the provisions of Regulation 21, Chapter I of the International Convention for the Safety of Life at Sea, 1960 and Article 23 of the International Convention on Load Lines, 1966 which are intended to provide the Organization with pertinent information regarding the effectiveness of the Regulations.

Being aware of the provisions of Resolution A.173(ES.IV) concerning participation in official inquiries into maritime casualties.

Having considered the Report of the Maritime Safety Committee on its thirty-third session,

Draws attention to the obligations of Contracting Governments concerning the investigation of casualties set out in the above-mentioned Conventions.

Urges Contracting Governments to provide the Organization with relevant information regarding lessons to be learnt and conclusions derived from the investigation of casualties.

Requests the Maritime Safety Committee to examine regularly such reports supplied by Contracting Governments and to recommend action as necessary.

Further requests the Maritime Safety Committee in consultation with the Secretariat to consider whether the Organization should take the initiative in listing serious casualties and requesting Administrations to give information regarding the inquiries held into them and their findings and thereafter to take any appropriate action to this end."

Annex 2.6

RESOLUTION A.440(XI)

15 November 1979

EXCHANGE OF INFORMATION FOR INVESTIGATIONS

INTO MARINE CASUALTIES

"The Assembly,

Recalling Article 16(i) of the Convention on the Inter-Governmental Maritime Consultative Organization concerning the functions of the Assembly,

Considering Regulation 21 of Chapter I of the International Convention for the Safety of Life at Sea, 1974, which requires Administrations to conduct an investigation of any casualty occurring to any of its ships when it judges that such an investigation may assist in determining what changes in the requirements of the 1974 SOLAS Convention might be desirable,

Noting that the Maritime Safety Committee has considered reports of investigations into serious marine casualties and has recognized the importance of free exchange of information between Governments and, in particular, the need for providing details of those casualties, Being aware that investigations into casualties, especially in the case of collisions, are often hampered by lack of exchange of information where ships under different flags are involved,

Having considered the recommendation made by the Maritime Safety Committee at its thirty-ninth session,

Urges Governments to co-operate on a mutual basis in investigations into marine casualties and to exchange information freely for the purpose of a full appraisal of such casualties."

Annex 2.7

INTERNATIONAL LABOUR ORGANIZATION CONVENTION No. 147, 1976 , CONCERNING MINIMUM STANDARDS IN MERCHANT SHIPS.

Article 2

(g) Each Member which ratifies this Convention undertakes to hold an official inquiry into any serious marine casualty involving ships registered in its territory, particularly those involving injury and/or loss of life, the final report of such inquiry normally to be made public.

Annex 2.8

UNITED NATIONS CONVENTION ON THE LAW OF THE SEA, 1982

Part VII High Seas

Section 1. General Provisions

Article 94

Duties of the flag State

7. Each State shall cause an inquiry to be held by or before a suitably qualified person or persons into every marine casualty or incident of navigation on the high seas involving a ship flying its flag and causing loss of life or serious injury to nationals of another State or serious damage to ships or installations of another State or to the marine environment.

   The flag State and the other State shall co-operate in the conduct of any inquiry held by that other State into any such marine casualty or incident of navigation.

CHAPTER 3

RADAR SIMULATORS

3.1 Simulation

From a technical point of view, simulation can be defined as a research or teaching technique designed to reproduce under test conditions various phenomena which are likely to occur under real conditions. The actual device utilized to carry out the simulation is called simulator and it can adopt many different configurations according to the objectives pursued. Therefore, once established what has to be simulated and bearing in mind the objectives of the simulation, a suitable system must be designed and developed to produce the approximation of reality needed. Three main interactive components are present in simulation. Those components are shown in figure 3.1.

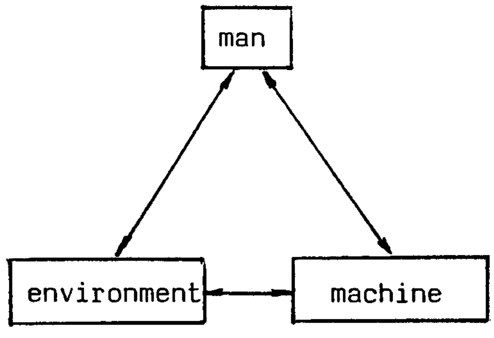


figure 3.1

As it has been defined, simulation has two main practical applications, namely teaching and research.

3.2 Why simulation ?

Simulation has been introduced as an adequate solution to overcome a number of limitations posed by on-the-job training and as a valuable tool for research as well. Safety, cost, time and training control are four important factors to be taken into account when considering the advantages of using simulators. Simulation allows to create hazardous situations in a safe environment, unusual conditions can be easily programmed and any situation can be repeated over and over at will. As an example, in navigation training nobody would put a ship in a hazardous situation in order to train somebody in anti-collision manoeuvres, while in a radar simulator such a situation can be programmed and repeated as many times as it may be necessary without any damage if a collision does occur. Simulation techniques have also found a wide field of application in research, considering the factors mentioned before. In the maritime field, studies on vessel traffic management systems, port development, safety of navigation in critical areas and human behaviour are examples of contributions of simulation to the development of such a field of activities. Simulation, however, has its own limitations as no simulator, no matter how sophisticated it might be, can ever be a 100% representation of real life. In training, the fact that safety is guarantied is an important constraint. In research, a number of assumptions will allways have a certain degree of uncertainty. Nevertheless, the achievement of the training objectives is more related to the validity of a simulator than its degree of realism. This aspect will be dealt with further on in this chapter in the context of radar simulators.

Therefore, simulation must be considered as a complement rather than a substitute of real life.

3.3 Marine simulators

The maritime community has been slow to accept simulation. However, simulation is used today in a wide spectre of activities and a fast development is taking place. This can be attributed to the technological advancement in recent years, especially in the field of data processing.

In an attempt to draw a broad classification of marine simulators they can be divided, according to the task they perform, into the following groups:

(a) Navigation simulators
(b) Cargo handling simulators
(c) Ship engine simulators
(d) Automation simulators

Furthermore, each group includes a number of applications and therefore can be divided into sub-groups. In this project, particular attention is given to radar simulators, which belong to group (a).

3.4 Development of navigation simulators

The first simulators of this kind introduced as teaching tools have been the radar simulators, which were primarily aimed at training in the use of radar as an anti-collision aid. Later on, different features were incorporated such as coastline generation, VHF communication, fog signals, echo sounding and a variety of electronic positioning systems. Accordingly, the training objectives became more ample including radar navigation, bridge procedures, SAR training, passage planning and electronic navigation among others. These simulators are still known as radar simulators although certain manufacturers and institutes have changed the name into radar and navigation simulators or simply navigation simulators. The characteristics of such type of simulators will be dealt with in more detail further on in this chapter. An additional development consisted in the introduction of external vision by way of light spots, shadows, computer generated imagery (CGI) or other devices, thus providing the trainee with a view of the world through the windows of his bridge together with the radar screen picture. Full bridge lay-out is usually provided and in certain simulators the bridge has been mounted on a moving platform. These simulators are called ship or ship handling simulators and have reached a high degree of sophistication. Their cost is also much higher than that of a radar simulator, and they require substantial building facilities for housing. On the other hand, ship handling simulators offer the possibility of training in ship manoeuvres to the extend of taking a vessel alongside in certain simulators. The field of research is also widened with this type of equipment.

In addition to these full-task simulators, a number of part task simulators have been developed. The modular concept of simulation allows training in the use of individual navigation instruments, usually feeding real instruments with simulated signals. By integrating part-task simulators, a complete ship handling simulator can be built.

A different approach to ship handling simulation is the recent introduction of micro-simulators. This type of simulators present either a bird's eye view or a panoramic view of the situation on a graphic display such as a video display unit or the radar screen adapted for that purpose. Therefore, the trainee is presented with a reduced scale synthetic picture of the world which allows him to manoeuvre the ship in a fairway or in port. These simulators are less expensive than full scale simulators, but their validity as training aids is under discussion.

3.5 Radar simulators

As it has been mentioned earlier, radar simulators have been primarily designed for training in radar operation at sea, but further developments have included other navigation features extending the field of application of the simulation to the extend that there is a tendency to change the denomination of those simulators. A sharp distinction is made, however, when the simulator is provided with external view in which case it is called ship handling simulator due to the fact that the radar is no longer the main source of information of the environmental situation. Therefore, for the purpose of this study, all those simulators which use the radar as the main information source about the ship's environment will be considered radar simulators.

Radar simulators, which began to be used in the 1950s, have become a common teaching tool in maritime colleges. The importance of radar simulators for radar training has been recognized at international level. At the International Conference on Training and Certification of Seafarers, 1978, a recommendation on radar simulator training was approved as Resolution 18, which has been reproduced in Annex 3.1 (page 49) of this project. IMO has encouraged the installation of such simulators in nautical colleges and provides substantial technical assistance on this matter.

Figure 3.2 is a basic block diagram of a radar simulator.

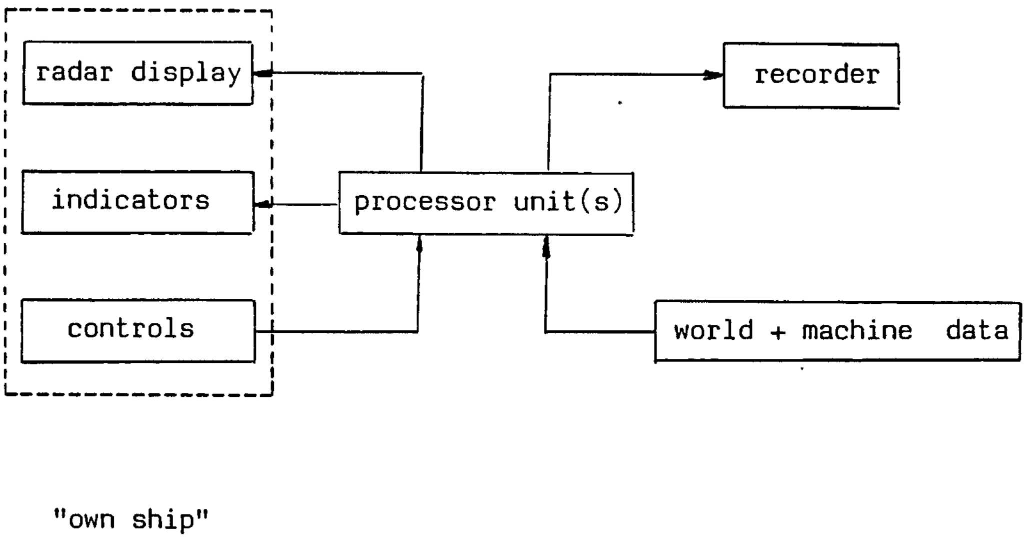


figure 3.2

The practical lay-out of the system includes:

(a) one or more of the so called "own ships", each of them being equipped with at least a radar set and the necessary instruments and controls to con the ship.

(b) a central processor unit, or decentralized micro-processors in more modern systems.

(c) an instructor station with the equipment needed to operate and monitor the system.

In addition to the hardware briefly described, the simulator also requires for its operation two main elements:

(a) software to meet the requirements of the simulation.

(b) adequately trained instructors.

Such a general description is obviously not enough to specify a radar simulator, and less to conclude that valid results can be obtained using such a system.

The validity of simulation is a measure of the functional correspondence between the simulation and the reality which is being simulated. A simulator used for training is considered valid if the knowledge and skills acquired by the trainee are applicable in future practice. If used for research, the results obtained in the simulator should agree with those which would have been obtained had the research taken place in real life. It is very difficult, however, to classify a simulator as valid or non-valid, as the results depend not only on the capabilities of the simulator itself but also on the instructor's skills , the training programmes and the trainee's skills as well. On the other hand, it is not always possible to compare research results obtained using a simulated man-machine-environment system with real life experiments. Nevertheless, a lot of research has been done in the field of validity with results which can be considered satisfactory. An important factor to be taken into account is that the operator of a radar simulator, and a simulator in general, must fully know the capabilities and limitations of the system he is using in order to carry out the type of training or research which leads to valid results.

So far, no international standards exist to specify the minimum requirements for a system to be considered as a radar simulator, but certain countries have established national requirements on that subject. Most of the radar simulators used worldwide have the following minimum characteristics:

(a) Hardware:

(1) Central processor unit or decentralized units.

(2) Instructor's console with facilities for exercise preparation, execution and monitoring.

(3) graphic plotter (X-Y or digital plotter)

(4) Electronic exercise recording and playback device.

(5) Own ship stations, each including a console to control course and speed of the ship and display heading, speed, RPM, helm and rudder angle, and a standard radar display unit with reflection plotter.

(b) Software:

(1) Own ship manoeuvring models with realistic hydrodynamic

behaviour in open waters and responding to the types of ships selected by the user, plus programmable models.

(2) Digital and/or optical coastline generation.

(3) Target generation.

(4) Radar display data generation.

(5) Instructor's console data generation.

(6) Data generation for graphic plotter and electronic recording and playback device.

(c) Lay-out:

(1) Instructor's room.

(2) Own ship cubicles.

(3) Briefing and debriefing room.

(4) Central processor unit room.

It must be emphasized that the above mentioned list describes the main minimum characteristics of most of the radar simulators in use. Many of them include a large number of additional features such as shallow waters effects, communication facilities, navaids, ARPA radars, etc. The specifications vary according to the objectives of the simulation and also follow the technological advancements. Those specifications which have to be met for the purpose of the research proposed in this paper will be analyzed in the next chapter.

An aspect which deserves special consideration, however, and that plays a very important role in the validation of radar simulator use is the behaviour of the "own" ships. All radar simulators include mathematical models of the dynamic behaviour of the "own" ships and certain simulators also include a simplified model to control the movement of the targets. The models designed for the "own" ships accept as inputs bridge commands and environmental data. In response to these inputs the simulated ship is expected to behave in a realistic manner, in accordance with the operational conditions.

The bridge commands may include:

(a) Main engine orders.
(b) Bow and/or stern thrusters orders
(c) Helm orders.

The environmental influences may be:

(a) Wind.
(b) Tidal streams and currents.
(c) Waves.
(d) Shallow waters effects.
(e) Interaction with other ships.
(f) Towing lines.
(g) Anchoring forces.
(h) Mooring lines.

The extend to which the inputs listed are included in the models provided with different radar simulators depends on the type of ship simulated, the objectives of the simulation and the cost of the system.

There is no commonality among models used by different manufacturers, as a number of solutions can provide similar results, and in many cases a manufacturer develops his own model without disclosing the information. The complexity required is in direct relation to the purpose of the simulation.For instance, a radar simulator used for manoeuvre training in restricted waters requires a much more sophisticated mathematical model than the same system used for navigation training in open waters.

Different models have been adopted by manufacturers of radar simulators. In Appendix I of this project the mathematical and physical principles involved are dealt with.

Shiphandling simulators, which have to perform a number of manoeuvring tasks, require high accuracy of the mathematical models. As the requirements of radar simulators are not so stringent, simplified versions of the equations can be used with good results.

Whichever the mathematical model used for the "own" ships in a radar simulator, a number of coefficients and time constants are included in the equations to simulate the behaviour of a particular ship. If the ship has been programmed by the manufacturer, the coefficients which do not represent environmental conditions are included as fixed values in the system. On the other hand, if the simulator offers the posibility of programmable ships, the coefficients must be accordingly chosen by the simulator user. In certain simulators, the range of validity of the behaviour of a specific ship can be extended by utilizing more than one set of equations, each set with its own coefficients, to describe the movement of the ship. Each set is used for a certain range of speeds.

3.6 Conclusion

Radar simulators are widely used today as a complement of navigation training on board. The field of application has grown as instructors have gained experience in the use of simulators and with the progress in electronic technology. A logical consecuence has been the extension of the use of radar simulators into the field of research.

Having considered the main characteristics of the casualty investigation process as well as the most important features of radar simulation, the next step is to analyze the application of radar simulators in that field. This is the subject of the following chapter.

Annex 3.1

INTERNATIONAL CONFERENCE ON TRAINING AND CERTIFICATION OF SEAFARERS,1978

RESOLUTIONS ADOPTED BY THE CONFERENCE

Resolution 18

Radar Simulator Training

THE CONFERENCE,

RECOGNIZING the vital importance of adequate radar training with regard to the safety of life and property at sea and the protection of the environment,

CONSIDERING that some methods of instruction in the use of radar do not achieve the desired level of proficiency of masters and deck officers,

NOTING that the International Convention on Standards of Training,Certification and Watchkeeping for Seafarers, 1978, requires such officers to possess an adequate level of proficiency in ship operations under all conditions of service,

RESOLVES to recommend that radar simulator training be given to all masters and deck officers,

INVITES the Inter-Governmental Maritime Consultative Organization to communicate this Resolution to all Governments invited to the Conference,

CALLS upon all Governments concerned to take due account of this Resolution as a matter of urgency.

CHAPTER 4

RADAR SIMULATORS AND MARINE CASUALTY INVESTIGATIONS

4.1 Introduction

Let's imagine a hypothetic situation in which two ships collide at sea, under conditions of restricted visibility. Both vessels have been detected in the respective radar screens. Despite this, the chain of events leads to a close quarters situation and ends up in a collision, with severe damage to both ships. An investigation into the casualty will commence and the first task of the investigator in charge is to try to establish the most probable course of events. All information is gathered including the evidence available and statements of witnesses. Based on that information, the situation preceding the accident is reconstructed and it is found that the collision could never have occurred and a safe CPA resulted from the manoeuvres carried out by the watchkeeping officers. However, the accident did in fact take place, which implies that something is wrong in the original reconstruction based on the information gathered. A reassessment of the situation must be done on a recurrent basis making certain assumptions until a solution is found which best responds to the circumstances and actually ends in a collision. Such a situation is not applicable to all the collisions which occur at sea, as many of them admit a straightforward reconstruction without any contradiction, but more than often the investigator will have to face an arduous task trying to establish the real chain of events.

A good graphical way of reconstructing the accident, which has been universally adopted, is the representation on paper of the tracks followed by the vessels involved. This has been done by nautical experts in hundreds of cases, plotting manually on paper or in a nautical chart the respective positions of the vessels concerned based on course and speed as a function of time until the accident occurs. As a matter of fact, this has been the only solution available for a long time. Obviously, such manual plotting is not an easy task and when certain discrepancies appear during the reconstruction, the graphic method can be especially tedious and time consuming, but these disadvantages had to be accepted as there was no alternative to the problem. In recent years, with the advent of digital computers and radar simulators as an application, an improved solution to the problem became available which takes advantage of the posibilities offered by such type of simulators. A number of cases have been put under test in radar simulators to help to establish the chain of events and the most probable cause or causes of the collision.

In this project, an analysis of this solution to the problem of collision reconstruction is made, establishing its advantages together with its limitations, and a systematic approach is suggested.

The first step is to identify the type of marine occurrences which can be subject to an investigation using a radar simulator and next the minimum specifications which such a simulator should comply with.

4.2 Marine occurrences subject to radar simulator analysis

4.2.1 Type

Radar simulators belong to the family of navigation simulators and therefore are applicable to situations in which the "own" ships are at sea performing navigational tasks. In fact, a radar simulator is a computarized position fixing device which in addition generates the appropriate radar signals in correspondence with the movement of the "own" ships. Hence, the marine occurrences which can be replayed using such a simulator are collisions at sea or groundings. In this study the analysis will be limited to collisions, in which full advantage of the posibilities of radar simulation can be taken. Groundings may involve a number of navigational problems including identification of land marks and shallow waters effects, which represent a restriction to the use of a number of less sophisticated radar simulators. However, the possibility of a reconstruction in the simulator should not be ruled out before an analysis of the particular case is made, as such an analysis might show that at least part of the grounding case can be reconstructed in the simulator based on its characteristic as a dead reckoning device.

A situation which has not been paid enough attention is that of a near miss, which fall in the category of incidents as defined in chapter 2 and that could also be investigated using simulation techniques. However, it is necessary to implement first a reporting system which has not been established yet. Therefore, it can be expected that such cases will be very uncommon.

4.2.2 Ship's environment

From the analysis of radar simulators made in the previous chapter, it is clear that such simulators reproduce conditions of restricted visibility, as normally the "own" ships have no windows, and if they are provided, it is only for the sake of fidelity of the simulated bridge without any useful information about the ship's environment. During radar training, the kind of exercises conducted in radar simulators are prepared under the assumption that the decision-making process is mainly based on the information obtained from the radar screen. This is equivalent to a situation in which the visibility is restricted to the extent that any visual sighting of a ship occurs too late to take any avoiding action. This characteristic suggests the type of collisions to be investigated, that is those which involve an extensive use of the radar as the main information source. In these cases, maximum benefit of radar simulation can be obtained because the reconstruction will include the radar picture seen on the bridge, which can be compared with the information provided by the statements of witnesses. However, before excluding casualties occurring in conditions of good visibility, such cases should be carefully studied. As it has been said before, the simulator is always working under the principle of establishing continuous position of the vessels as a response to speed, course and environmental influences inputs. Therefore, this feature of radar simulators can be used with great advantages to obtain a graphic reconstruction from a digital plotter, even if the radar picture is left out.

An aspect to be considered is the type of radar installed on board the vessels involved in the collision and the presentation which has been in use. This question will be analysed when establishing the radar simulator requirements.

Furthermore, as it has been previously considered, radar simulators are able to provide a good response of ship acceleration, deceleration and turning in deep waters, while simulation of the behaviour of the vessel in shallow and restricted waters is limited to a few very advanced simulators. Even being such the case, there are situations in which it is hardly possible to simulate the behaviour of a particular ship involved in a collision, to provide a valid result. Consequently, those cases shall be excluded from the analysis.

4.2.3 Number of ships involved

It seldom occurs that more than two vessels participate directly in the accident, though other ships may contribute indirectly. As the vessels colliding will be represented by the radar simulator "own" ships, the cases which will be considered are those in which two vessels have actually collided, while other ships in the vicinity may have had a passive role. However,those ships will still be taken into consideration during the reconstruction.

4.3 Minimum radar simulator specifications

A radar simulator that will be used to investigate a case of collision at sea should satisfy a certain number of requisites in order to provide valuable information regarding the most probable course of events. The main characteristics and features of radar simulators have been analysed in chapter 3. Now, specific requirements will be established taking into account the type of marine occurrences to be reconstructed.

4.3.1 "Own" ships

It is required that the radar simulator be equipped with at least two "own" ships, each of which will represent one of the vessels involved in the collision. The ships must be fitted with a radar set, engine control and rudder control.

If standard radars have been used on the bridges of the ships involved, it is convenient to know the kind of presentation in use and the simulator set should be able to be switched to that mode. In recent years there has been a large increase in the use of ARPA radars and due to international requirements, it can be expected that the number of ships equipped with those radars will continue to increase. As a consequence it can also be expected that the number of collisions occurring while an ARPA radar was in operation will be larger. Although ARPA radars must fulfil a number of minimum requirements to be considered as such, different manufacturers have chosen a variety of presentations to solve the problem of collision avoidance. It is not likely to occur that a radar simulator is provided with an ARPA radar of the same manufacture as the one on board a ship which has collided and less if both ships have been using ARPA radars of different manufacture. As a matter of fact, certain simulators have been equipped with ARPA radars which do not respond to any standard set in the market. Even if the simulator is equipped with the same ARPA sets as the ones installed on board the ships involved in the casualty, the information which may have been collected on board from the ARPA can not be reproduced in the simulator due to the number of factors which influence the processing of data. Therefore, the information concerning ARPA data has to be considered as additional, and the case replayed using the standard radar.

The dynamic behaviour of the "own" ships must respond to mathematical models which can be adapted to simulate the manoeuvring characteristics known of the actual vessels which have participated in the casualty.

4.3.2 Targets

In addition to the "own" ships, in certain cases other vessels play a passive role in the collision and those ships must be included in the reconstruction of the case. For that purpose it is necessary to use targets, that is radar echoes representing ships which are under control of the instructor. It is not required that these targets be provided with a complete mathematic model as their manoeuvre can be controlled from the instructor's console and on the other hand, the ships they represent are only indirectly involved in the collision. It is difficult to establish beforehand the maximum number of ships which will be in that situation before knowing the case, and therefore it can only be stated that the radar simulator should be provided with as many targets as significant traffic was present at the time of the collision. Normally, four targets for this purpose should be sufficient to represent the picture of the traffic surrounding the ships which participated in the collision, and having influence in the accident.

4.3.3 Coastline

The number of coastlines available in the library of radar simulators is fixed and limited. More than often the area in which the collision occurred is not included. However, as the type of accidents to be investigated are collisions at sea, the influence of the coastline in the analysis of the case is limited. If it is required to have certain fixed reference marks such as light-vessels, light-houses or others, it is always possible to represent them with targets in a fixed position. In such cases, in addition to the targets required to include traffic, extra targets shall be needed as reference marks according to the circumstances.

4.3.4 Instructor's console facilities

4.3.4.1 "Own" ships characteristics

The radar simulator should be provided with the facility to modify the coefficients of the mathematical models of the "own" ships in order to adapt them to the real vessels, and this process should be independent for each of them. As a result of the instructions, acceleration, deceleration and turning rate must respond to the behaviour expected of the ships involved in the collision. The cases to be analysed have been limited to collisions in deep waters in order to avoid situations in which a radar simulator might not be able to respond to the real behaviour of the vessels under other circumstances. Shallow water situations are limited to a few advanced radar simulators.

4.3.4.2 Target control

Those vessels that represent the traffic in the area of the collision, except the two vessels actually colliding, are under control of the instructor and therefore it must be possible to alter course and speed at any time from the console according to the situation.

4.3.4.3 Playing areas

A basic requirement is that the geographical location of the ocurrence must be reproduced in the simulator, even if the coastline is not represented . Normally this is not a restriction as most radar simulators cover any geographical area of the world, and if not, at least the areas commonly used for navigation are included. If the longitude is not covered, it may be replaced by a longitude within the limits of the simulator without introducing any change in the final results.

4.3.4.4 Environmental influences

In the analysis of the marine casualties under study, a number of external factors may be present. Those are wind, current and precipitation. The effect of wind will result in a certain drift of the ships and sea clutter on the radar screen. Advanced radar simulators include the effect of wind drift, but as such is not the case in many radar simulators, the instructor must normally calculate this effect and introduce wind drift manually. Sea clutter must be electronically generated by the software and it is desirable that its intensity can be graduated. Current is an environmental factor which has to be programmed by the instructor. Normally both vessels involved in the collision will be influenced by the same current. However, if the case is reconstructed starting a considerable time before the accident, the efect might be different and therefore the possibility of programming independent currents for each ship is not a requirement but will simplify the work of the operator in those cases. Precipitation may have an influence on the picture seen on the radar screen, and in certain cases it can be an important factor in the detection of echoes. Most radar simulators do not provide simulation of rain clutter and if they do, the result is generally not realistic. On the other hand, it is very improbable that good information about rain or showers is known after the collision occurred. Therefore a situation of heavy rain or showers may pose a restriction to the analysis of a case using simulation.

4.3.4.5 Radar response

In addition to the sea clutter mentioned before, the instructor should be able to program radar antenna height and echo strength according to the characteristics of the ships involved, which will affect the detection of echoes.

4.3.4.6 Cinematic information

In order to monitor the development of the situation, during the analysis of the case the console should provide information about position, course, speed, CPA and TCPA of all vessels concerned. It is desirable that the position of any vessel be expressed as bearing and distance from both ships involved in the collision.

4.3.4.7 "Freezing"

This term means the possibility of detention of an exercise without modification in the final results, in order to study the situation at any particular time and it is an important feature both during the testing of a case and its demonstration.

4.3.5 Recording devices

4.3.5.1 Graphic plotter

This device, which can be considered as the graphical track recorder, is a fundamental tool to plot the positions of the vessels and follow the development of the collision situation. The graphic or graphics that will be obtained replace the manual plotting of the case.The number of ships that can normally be plotted in a graphic plotter is limited but not less than 8 vessels can be handled by such devices, which is more than enough for the purpose of collision investigation. It is advisable to have different scales in order to enlarge the area around the point of collision and clarify the situation during the last minutes before the occurrence. A plot of the position of the ships every minute, which is a standard interval, provides a good information about the development of the events.

4.3.5.2 Electronic recorders

A number of radar simulators include electronic devices such as magnetic tape recorders, floppy disks and video recorders aimed at recording the exercises done and replaying the situation during the subsequent debriefing. For the purpose of casualty investigation such recorders are not a must but rather a complement to the graphics obtained from the graphic plotter and therefore if they are included in the simulator they should be used to show a complete picture of the case.

4.3.5.3 Printers

A print out of the cinematic information mentioned before at crucial times will replace the manual recording of that data and therefore, although the printer does not form part of the minimum requirements it should be used if the radar simulator has such facility.

4.4 Conclusion

The use of radar simulators in casualty investigations is not presented as a new method of reconstructing collisions at sea but rather as an improved alternative to the manual plotting. The type of collisions has been restricted to the cases in which a radar simulator complying with the minimum specifications established before in this chapter can provide a faster and more accurate solution. Once it has been established that a case can be subject to investigation in the radar simulator, taking into consideration the limitations presented in this chapter, the operator of the simulator will be faced with the task of finding a solution to the problem which is seldom easily reached. In the next chapter guidelines are given which should help the operator to carry out the investigation work.

CHAPTER 5

THE TASK FOR THE OPERATOR OF THE SIMULATOR

5.1 Introduction

This chapter deals with the practical work which has to be carried out by the operator of the simulator in order to reconstruct a casualty and establish the most probable chain of events. Normally this job should fall in the hands of the radar simulator teacher or instructor, who will be referred to as the operator, and who has both the nautical experience and the knowledge and practical skills in handling the simulator required to do the reconstruction work.

It can be expected that not two casualties are alike and therefore no strict rules can be applied. However, it should be possible to establish basic procedures and gidelines to help to tackle any collision problem, and an attempt in that direction is made here.

5.2 Sources of information

To start to deal with a collision case, it is necessary to collect all the information available about the casualty, which includes witnesses statements and evidence, obtained by the investigator or the investigating team. The way by which the information will be made available to the operator and its amount depends upon his position in the investigation process. The operator might be a member or an assessor of the investigating body, or be approached by the plaintiffs' and/or defendants' solicitors. In any case, it does often happen that the information is scarce or partial, specially as far as facts are concerned, which will make the analysis of the accident difficult. Once all documentation is in the hands of the operator, it should be carefully studied in order to establish whether the reconstruction can be attempted or additional information is required. However, there is always a limit in the data available and the question is whether the reconstruction of certain cases be abandoned because of this limitation. As the result of a reconstruction represents a probability rather than a certainty, the tests might be carried out in all cases and the final results graded in accordance to the degree of confidence. On certain occasions it may happen that no information at all can be obtained from one of the parties to the casualty, either because it is not disclosed or the ship and the crew have been lost, in which case the reconstruction can only be carried out based on the data provided by the other party and/or external sources. Those external sources of information should always be consulted, including if applicable:

(a) weather reports

(b) current data

(c) tidal information

(d) notices to mariners

(e) records of shore communication stations

(f) reports of vessels in the vicinity

(g) ship's data documentation

5.3 Initial reconstruction

As a starting point, the first reconstruction should repoduce the tracks followed by each of the ships based on the witnesses statements together with the evidence produced, regardless of the claims or the information provided by the counterparts. In an ideal situation, this test should be based on positions obtained on both ships, manoeuvres carried out with time of execution, and data about the ships and their behaviour. However, a problem which can be expected is that complete information about the characteristics of the vessels is not available. As it has been established in Chapter 4, the simulator should be able to reproduce the manoeuvring characteristics of the vessels involved in the collision, which does not imply that it will always be possible to feed the simulator with accurate data. As a matter of fact, more than often no information at all can be obtained, which means that in order to continue the reconstruction the operator will have to produce his own figures, based on data about ships similar to the vessels involved in the collision and/or his own experience. It should also be taken into consideration that even if complete information is available, the accuracy of the information provided can be seriously questioned when it comes to establish values such as the amount of rudder angle or the response of the engine without data recorders. On the other hand, in many cases there is a discrepancy between manoeuvring data obtained during trials and the actual behaviour in a specific situation.

If, as a result of the reconstruction, both ships arrive at the same time in the same position, which is the collision point, the problem has been solved and the plot obtained from the graphic plotter together with the report prepared by the operator and an electronic recording, if available, will constitute the documentation provided by the test on the radar simulator. In many cases, however, it will be found that a controversy appears in the result of the analysis and no collision occurs, which means that no straightforward solution exists. Nevertheless, this initial reconstruction should always be included in the report before any alternative solution because the statements of the witnesses must be taken into account in a first attempt to establish the course of events, even if it is obvious that it will not lead to a collision. In fact, this test will be the proof that alternatives have to be looked for.

5.4 Additional tests

It is clear that when ambiguities appear, the most difficult task starts for the operator. He must look for alternative solutions until he finds the most probable chain of events which lead to the collision, now considering not only the statements of the witnesses but also all the data. The most important factors to be analysed are considered.

5.4.1 Position of collision

Hopefully, the position of the collision will be agreed upon by the parties, but in many cases both will report different positions. If no evidence can be gathered (such as position of wreck or information from other sources) then both positions should be plotted during the reconstruction so as to assess which one is more reliable, although both may be erroneous. Prevailing currents and wind in the area may help the operator to overcome the ambiguity. The positioning methods utilized by the officers on watch should also be analysed to eliminate positioning errors.

5.4.2 Time of collision

There may appear discrepancies in the times of collision reported by the parties. The difference can be attributed either to lack of synchronization between the clocks on both bridges or misjudgement of time data. If no evidence is available to solve the ambiguity, the tests in the simulator will have to be made considering the information provided by both ships and the most probable time will be the result of the analysis in the simulator.

5.4.3 Ships' positions

If the tracks followed by the ships, or the positions at sufficiently short intervals are known, they constitute very valuable information prior to the accident. Due to the lack of systematic data recording systems on board ships, the best evidence available is the navigational chart or the log book, provided that the positions have been transferred to that book. Such information can enable the operator to establish most probable true courses and speeds, together with effects of wind and/or current. Again, as has been considered before, errors in the position fixing methods must be taken into consideration.

5.4.4 Manoeuvres

In the absence of evidence, the task of establishing the manoeuvres carried out by the ships involved will consist in a series of trials making use of the most reliable information and taking into account the degree of confidence which can be attributed on the veracity of the statements. As a result of this analysis, modifications in the original versions must be introduced until the ships actually collide. The corrections introduced should, however, be based on logical assumptions which can be justified in the context of the real general situation.

Course recorders, if operating properly, supply extremely important information about course alterations, so that the operator should always try to collect and include that piece of evidence.

5.4.5 Angle of impact

This is another piece of information to establish the manoeuvres made before the collision. An approximate collision angle is in most cases remembered by the witnesses although it may also raise controversy. If a surveyor has access to both ships involved in the accident, an examination of the damages suffered by the vessels can usually provide a good approximation of the angle of impact, either to corroborate the witnesses' statements or to establish its value.

5.5 Documentation

Bearing in mind the purpose of the reconstruction, that is to establish the most probable cause of the collision, and considering that the final conclusions do not represent with absolute certainty the real course of events but rather what is believed to have happened based on the information gathered, the operator of the simulator should prepare all the documentation required to support the conclusions.

It was mentioned before that the bases of the report are the plots obtained from the graphic plotter. These include the original version and all the alternatives analysed until a final conclusion is arrived at. When necessary, and especially in the final reconstruction, it is advisable to make expanded graphs with shorter plotting intervals if this facility is included in the radar simulator, to show in more detail the last events before the collision. Each graph must be accompanied by the pertinent information about its content and meaning. In radar simulators equipped with electronic recording devices, the different reconstructions should also be recorded by that means, which will enable the demonstration "in situ", with the advantage of the availability of radar pictures of the situation. Even if no electronic recording can be made, it is always possible to show the situation on both bridges simply by replaying the case in the simulator. Careful analysis of the events can be done "freezing" the test at any moment. Those radar pictures can be compared with the radar information remembered by the parties, although it can be expected that very seldom witnesses will actually participate in the reconstruction during the investigation process.

Finally, evidence such as navigational charts, course recorders, position recorders, log books, engine data recorders and whichever else is available and pertinent should form part of the documentation to support the conclusions of the operator.

5.6 Conclusion

The task of reconstructing a collision at sea represents a challenge for the operator of a radar simulator as one can be almost certain that ambiguities and discrepancies will occur, and the information available will be scarce.

It is important to remember that the purpose is to establish the probable course of events, as the key to ascertain causes and propose measures for avoidance of similar casualties to happen in the future, in the context of safety at sea. Therefore, no efforts should be spared to try to obtain results compatible with reality, but on the other hand, an infallible conclusion should not be expected due to the number of variables involved and which can not always be completely known. In this context, the installation of data recorders, including radar video recording, on board ships should be given consideration and an analysis of the subject is done in chapter 7.

A number of cases of collisions at sea have been reconstructed using radar simulators and in the next chapter, four cases have been selected as examples of typical situations and the subsequent analysis made.

CHAPTER 6

ANALYSIS OF CASES

6.1 Introduction

In this chapter, four cases of collision at sea based on real occurrences are analysed with the aid of a radar simulator and the results are presented. The simulator used meets the minimum requirements stated in chapter 4, and includes four "own" ships. In addition to a digital plotter, a floppy disk unit for electronic recording is fitted. Therefore, although only graphic results have been included in this analysis, a full picture of the situation can be stored for replay of each case at any time. The graphs drawn by the digital plotter reproduce the situations in a Mercator projection.

As can be expected, the information gathered in each of the cases is very voluminous. Therefore only the most relevant part of it has been included here and a summarized analysis of the collisions has been done. Neither blame nor apportionment of fault have been considered.

6.2 Case 1

This is a case of collision in dense fog between a loaded cargo vessel of 800 TDW, 55 metres in length and full speed about 9 knots, referred to as X and a vessel in ballast of 320 TDW, length 40 metres, full speed about 8 knots, referred to as Y. The collision occurred at 0310 in position 56 28.5 N and 16 16.0 E, obtained from a Decca fix. As a result of the collision, ship X capsized and sunk, and all documentation was lost.

A reconstruction of the events as recalled by the witnesses on ship X resulted in the following summary:

At about 0215 of the day of collision the ship passed close to Trädgårdsgrund lightbuoy (56 37.6 N, 16 21.7 E) with reduced speed due to bad visibility on a course 196 true. At 0240 an echo was detected on the radar screen at about 12 miles fine on the port bow and approaching the heading marker. Three successive alterations of course of 5 degrees to starboard where carried out when the range to the target was about 5.5 miles, 4 miles and 2.5 miles. It was observed that the echo always continued to approach the heading marker. A new course alteration of 10 degrees to starboard was ordered, no time registered and with the echo very close, no range measurement possible. By reducing pitch the speed was reduced to slow ahead. After 2 or 3 minutes a white light and later a green light was observed about 45 degrees to port, very close. Hard-astarboard and dead slow ahead was ordered. At 0310 the collision occurred. Visibility was estimated in 100 metres. During the events both captain and mate where on the bridge and the auto-pilot was in use.

It was claimed that the collision occurred because the echo altered course to port. No radar plotting was made.

Vessel Y presented chart and log-book at the investigation. The narrative based on documents and memory is as follows:

At 0220 of the day of the collision the ship passed Utgrunden light house (56 22.6 N, 16 15.7 E), range about 1 mile on course 010 true. The echo of a vessel was first observed on the radar screen at about 7 miles, 5 degrees to starboard. When the vessels approached, the speed was reduced to half and later to dead slow by reducing the pitch. The echo disappeared in the sea clutter. The white and red lights of a ship were observed at about 50 metres away and the collision occurred. The ship had been steered on auto-pilot and both captain and mate were on the bridge. It was claimed that according to the observations of the echo, a safe CPA resulted and therefore no alteration of course was decided. No radar plotting was carried out.

In order to take into account the versions of the witnesses, a first test should be made based on that information, which in this case was omitted because at reduced speed ship X could not arrive in time to the collision position. This is clearly shown in the first reconstruction made here. The reconstruction started with a plotting of the tracks of both ships, assuming full speed and no change of course. From an analysis made of the earlier navigation of the vessels, a mean speed of 9.5 knots for X and 8.5 knots for Y. The results are shown in figure 6.1.1 (page 94), in which the targets represent the following:

01 : ship X

02 : ship Y

10 : Utgrunden light-house

12 : buoy three cables westwards of wrecked ship

13 : position of collision

14, 15, 16 : fixed targets positioned in same longitude and 1 minute of latitude apart to be used as distance scale

The plotting interval is 2 minutes, and starts at 0220 when ship Y passed Utgrunden lighthouse. The position of X at that time corresponds to the DR five minutes after passing Trädgårdsgrund lightbuoy. The plotting is stopped at 0302 and shows that even at full speed, ship X could not reach the collision position at 0310. It also shows that without any course alteration ship Y headed towards that position but a reduction of speed should be considered in order to reach that point at 0310. From this reconstruction it can also be concluded that at 0240 ship X could not have detected the echo of Y at 12 miles.
A second attempt was made, modifying the position of vesel X at 0220 so that Trädgårdsgrund lightbuoy was abeam at 0205, ten minutes earlier than stated, and which would allow the vessel to reach the collision point at 0310. Furthermore, when the distance between ships was 5.5 miles, 4 miles and 2.5 miles, the course of ship X was altered 5 degrees to starboard at a

rate of 60 degrees per minute. These events occurred at 0245, 0250 and 0255. A new alteration of 10 degrees to starboard was done at the assumed time of 0259, when the ships were 1.4 miles apart. The result of this reconstruction is figure 6.1.2 (page 95). It shows that the collision still does not occur as ship X will clear point 13 on her port side with a CPA close to one mile.

Still considering the course changes stated by ship X, which is probably more reliable than the distance obtained from the echo at the time of those changes, and assuming that a reduction of speed occurred only very close to the collision, several attempts were carried out in the simulator. The reconstruction of the most probable chain of events has been summarized in table I, with course and speed orders, and the corresponding plotting is shown in figure 6.1.3 (page 96).

Table 1

time	ship X		ship Y		distance
	course	speed	course	speed	
0252	201	9.5	010	8.0	3.5
0257	206	9.5	010	8.0	2.5
0258	206	9.5	010	5.0	
0302	206	9.5	010	3.0	
0303	211	9.5	010	3.0	0.6
0304	221	3.0	010	3.0	0.4
0306	hard-a-st.	3.0	010	3.0	0.15
0309	collision				

It is noted that the speed of ship Y has been reduced to 8 knots so as to reach point 13 at the time of collision which in the reconstruction happened at 0309. The speed reductions of both vessels have also been estimated, as no reliable information was available. The speed of ship X had to be considered full ahead until 5 minutes before the collision in order to arrive to that position at 0309. The angle of impact amounted to 80 degrees. Figure 6.1.4 (page 97) is the same final reconstruction but using a larger scale. Therefore, it starts at 0250 and the plotting interval is one minute.

6.3 Case 2

This accident was a collison in very low visibility between a fully loaded tanker (referred to as X) of 1200 TDW and a length of 75 metres, and a fully loaded cargo vessel of 2100 TDW and a length of 85 metres (referred to as Y). The collision occurred in position 55 28.0 N, 14 38.5 E at 2245. No wind or currrent was reported. The impact was at approximate right angles and the vessels suffered minor damages.The statements obtained from both vessels were as follows:

Vessel X:

The ship was proceeding on course 058 at a speed of 10.5 knots. An echo was observed on the radar screen at about 2220, 5 degrees to starboard (radar on relative motion and head up) and at a distance of 8 miles. A plotting was initiated on a plotting sheet. Six minutes later the same echo was plotted again together with another one about 130 degrees to starboard, distance 1.8 miles. A third echo was also plotted on the heading marker. The master and the mate on watch discussed the possibility of turning to starboard to avoid both vessels ahead but the master decided to maintain course so as to keep a safe distance to the high speed vessel on parallel course on her starboard side, which was overtaking. Course and speed were maintained until the distance to the echo approaching fine on the starboard side was about 1.5 miles, when the speed was reduced to 5 knots. Later, a new speed reduction to about 2 to 3 knots was made but just before the collision. When the collision occurred, the ship was seen turning hard to starboard. Ship X did not make any attempt to alter course until just before the collision. The ship was being steered by auto-pilot.

Vessel Y:

The ship was on course 238 degrees, at a speed of about 10.5 knots. On the bridge was the master and a deck boy. The autopilot was in use. The radar was in operation and working on the 5 miles range scale, relative motion and head up. At about 2230 a target was observed approximately 5 miles ahead and 1.3 miles to port. When the echo was just within 4 miles, the master concluded that it was approaching on a constant bearing and that there was a risk of collision. He went to the autopilot and changed course to 280 degrees. When the ship was on her new course the echo appeared about 50 degrees to port. The speed was reduced to 5 knots. An observation of the movement of the target showed that it was now approaching on constant bearing. The master changed to manual steering, put the rudder hard-a-starboard and reduced speed to dead slow. However, the echo continued to approach. Ship Y reversed to full astern but at 2245 the collision occurred. The master claimed that the accident happened due to vessel X turning to port, which destroyed his avoiding manoeuvre to starboard.

The plotting carried carried out by vessel X has been reproduced with comments in figure 6.2.1 (page 98). In this collision case, a narrative was also obtained from a ship (referred to as Z), which before the collision was 2.0 to 2.5 miles on the starboard quarter of vessel Y. This narrative is as follows:

Vessel Z:

The ship, a general cargo vessel of 2100 TDW, length 90 metres, was on course 238 degrees and sailing at a speed of about 11 knots. She was slowly overtaking vessel Y. On the bridge was the master and a seaman whom the master was training in radar observation and plotting.The radar was in relative motion, head up and gyro synchronized. At about 2220, when vessel Y was bearing 190 degrees and at a distance of about 10 miles, another echo was plotted about 10 miles away, which seemed to pass on a reciprocal course approximately 2.5 miles on the port side. Both the master and the seaman plotted the echo until it approached to 6 miles. Then the range scale was changed to 6 miles and a new plotting was started. The master noticed that the echo now proceeded on a steady course right into a collision with vessel Y. It had been observed that ship Y had changed course and reduced speed because the echo was closer to the heading marker and nearer. The speed was reduced and an attempt was made to call the attention of vessel Y and warn her about the dangerous situation. At 2245 the collision occurred.

The reconstruction work started with a plotting of the situation according to the narratives of vessels X,Y and Z. The results are reproduced in figure 6.2.2 (page 99). The targets marked represent:

01 : vessel X

02 : vessel Y, from vessel X plotting

03 : vessel Z, from position of Y and her plotting from Z

10 : collision position

11 : high speed vessel plotted by X, overtaking on her port side

12 : vessel Z, from vessel X plotting

13 : vessel X, according to statement by vessel Y

14 : vessel X, according to first plot made by vessel Z

20, 22 : fixed targets one mile apart, for scaling purposes

The reconstruction started at 2220 and was stopped at 2245. The plotting interval selected was 2 minutes. Target 13 was positioned in such way that at 2230 it could be detected by vessel Y about 5 miles ahead and 1.3 miles to port, and on a collision course. At 2233 the echo should be at 4 miles and therefore the course of Y was altered to 280 degrees, at a rate of 50 degrees per minute. At the estimated time of 2235, the speed of ship Y was reduced to 5 knots. As for ship X (target 01), her speed was reduced to 5 knots at 2240 and to 3 knots at 2244 being both times estimated as no accurate information was given. The graph shows that the distance between ship Y and target 13 at 2245 was 1.25 miles, and from ship Y to the collision point 0.85 miles. Therefore, it is probable that the manoeuvres carried out where started later than estimated. It is also noted that at 2230, targets 11, 13 and 14 are within 0.6 miles of each other, and remembering what they represent, it suggests that the three targets were in fact only one echo, that is the fast ship overtaking vessel X. As stated by Y, the echo approached from 5 miles to 4 miles when it was assessed that there was a collision situation. From the plotting made by vessel X, the estimated speed of the fast ship was 20 knots which means that at the combined speed of 30.5 knots the time taken to cover a distance of 1 mile was 2 minutes. A cross track error in plotting of 0.15 miles is enough in this case to give an impression of risk of collision for a target in opposite course.

A new reconstruction of the accident was carried out, starting at 2235 and estimating 2238 as the time of vessel Y changing course to 280 degrees and 2239 the time of reduction of speed. The plotting interval was 2 minutes and the digital plotter was stopped at 2245.The result is shown in figure 6.2.3 (page 100). At the time of collision the distance between X and Y was still 0.45 miles. Therefore new attempts have to be made introducing corrections in the manoeuvres carried out. Figure 6.2.4 (page 101) is the reproduction of one of the tests, starting at 2235 and plotting every two minutes, in a new scale. The manoeuvres assumed for vessel X and vessel Y are summarized in table 2.

These assumptions produced a final situation in which both vessels were 0.25 miles apart at the time of collision, which according to the graph shows that still some adjustments in the manoeuvres carried out by ship Y are required in order to bring that distance to zero. The course alterations of vessel Y end up in a right angle situation with respect to vessel X at 2245.

table 2

time	vessel X (target 01)		vessel Y (target 02)	
	course ord.	speed ord.	course ord.	speed ord.
2240	058	5.0	280	10.5
2241	058	5.0	310	5.0
2242	058	3.0	310	5.0
2244	058	3.0	330	2.0

6.4 Case 3

Case of collision between a tanker (referred to as X) of 22600 GRT, 205 metres in length and powered by a diesel engine with single screw, and a general cargo vessel (referred to as Y) of about 15660 GRT, 185 metres in length also powered by a diesel engine with a single screw.

According to vessel X, the collision occurred at about 0217 hours in position 57 34.1 N, 9 28.2 E, this position having been obtained as a DR from the satellite navigator. According to vessel Y, the collision occurred at 0220 hours in position 57 35.0 N, 9 30.0 E. The following narrative was obtained from vessel X:

Vessel X:

The vessel had in operation two radar sets, one of 3 cms.

in relative motion and the other of 10 cms. in true motion. At midnight, the lights of a ship proceeding in the same direction were seen broad on the starboard bow at about 1 to 2 miles distance, and the echo of another vessel going the same way was detected. At about 0100 the stern light of the second ship were sighted. Shortly after 0118 it was necessary to alter course about 10 degrees to port, to pass that ship, which happened at about 0140 hours. Positions were obtained from observations using the 3 cms. radar and from satellite fixes. The last position before the collision was obtained from the satellite receiver at 0150 and was marked on the sea chart. Shortly before about 0217 hours the vessel was on course about 240 true and sailing at a speed of approximately 14.5 knots. The wind was west southwesterly, force 3, weather fine with moderately good visibility and there was no tidal or other current particularly noted. In these circumstances, shortly after overtaking another vessel on the starboard side, an echo was seen on the 10 cm. radar at about 12 miles fine on the starboard bow. After a short interval it was determined that the ship was on reciprocal course and would pass safely starboard to starboard. The echo was kept under observation and when it came to 6 miles distance the observation was continued on the 3 cm. radar set on head up mode and 6 miles range scale. When the echo closed to 2 miles a visual search started and two masthead lights together with a red side light were sighted. The ship was distant about one mile, bearing about 40 to 50 degrees on the starboard bow and heading 100 to 110 degrees, approximately. It was seen altering course to starboard. The engine was stopped and the helm put hard-a-port. Immediately thereafter the vessels collided at an angle of about 80 degrees with the port side of the other ship striking the bow of vessel X.

As for vessel Y, it was much more difficult to obtain an account of the events, which was as follows:

Vessel Y:

At 0000 hours the position of the ship was 57 17.5 N and 08 35.4 E. The course was 058 and the speed 14.5 knots. At 0040 the visibility was reduced to 1 mile. At 0153 a Decca fix was obtained, the position being 57 31.3 N, 09 15.0 E and the echo of a ship was detected on the radar screen at about 12 miles and 5 degrees on the starboard bow. At 0155 the course was altered to 088 degrees, manoeuvring to three ships coming against the vessel at a distance of 7.5 miles. During the next three to four minutes when vessel X should have been some 25 degrees on the port bow she was carefully observed but as she took no action, the course was altered to 100 degrees. At a very late stage, the wheel was put hard-a-starboard and at 0217 ship X was seen at a distance of one mile on the port side, turning to the right. At 0220 the collision occurred.

In this collision case, a statement was also obtained from the ship which had been overtaken by X. That ship is referred to as Z and her account is as follows:

Vessel Z:

The ship is a single screw motor ship of 9350 GRT with an overall length of 153 metres and a breadth of 20.3 metres. During the night of the collision the weather was calm, with fog patches, and occasionally the visibility was as low as half a mile. A position was obtained at 0110 and the course was put to 237 degrees, speed about 12 knots. At about 0200 hours the vessel was overtaken on the port side by ship X, which passed unnecessarily close. The steering was changed to manual when X approached. At the same time, the echo of vessel Y, bearing approximately 250 degrees and distant 5 to 6 miles was detected on the radar screen. The radar in use was a situation display radar. The observation of this echo showed that her bearing was closing on the bow and the speed was reduced. Vessel X and vessel Y were observed on the screen while they approached each other. When the distance was about 2 cables, a heavy alteration of course to starboard by vessel Y was observed. No alteration of course of X was detected until the collision occurred. At that time the vessel was at a distance of about 1 to 1.5 miles from the collision position.

As evidence, the navigation chart and track recorder of vessel X were obtained. The track recorder showed from 0049 to 0217 a course of 240 degrees, except for an alteration to 227 degrees between 0124 and 0143, at a turning rate of about 30 degrees per minute. At 0217, a sudden and drastic course change to port was observed, at an initial rate of 360 degrees per minute decreasing until the course stabilized on 105 degrees.

A first reconstruction of the case is shown in figure 6.3.1 (page 102). This reconstruction is based on the satellite position obtained by vessel X at 0150, which her chart showed to be 57 36.8 N , 09 37.8 E, and the Decca fix obtained by Y at 0153. The targets on the plotting represent:

01 : vessel X

02 : vessel Y

10 : vessel Z

11 : unknown vessel sailing parallel to X

12 : collision position reported by X

13 : collision position reported by Y

15, 16, 17 and 18 : fixed targets one mile apart for scaling purposes

The plotting was started at 0150 assuming vessel Z abeam of X and 0.6 miles apart sailing on course 237 at 10 knots. The plotting interval selected was 2 minutes and the course alterations for vessel Y were as shown in table 3.

table 3

time	course
0155	088
0200	100
0212	160
	(hard-a-starb.)

This test shows that at 0214 ship X passed at a distance of 0.25 miles of the collision point reported, while Y ended up at 0220 hours 5.9 miles away from position 13 and 4.65 miles away from position 12.

A second test was made relying on the position given by X and shifting the position of vessel Y so that at 0150 the echo of X should have been detected bearing 062 degrees at a distance of 11.8 miles. The subsecuent manoeuvres as stated by Y still took the vessel to a position 3.5 miles apart from 12 and 4.2 miles from 13. This plotting was started at 0150, with a plotting interval of 2 minutes and is shown in figure 6.3.2 (page 103).

Additionally, a test was made considering the position stated by Y to be correct and therefore shifting the positions of the three echoes to maintain same bearing and distance of X from Y as before. The plotting started at 0150 with two minutes interval. The results have been reproduced in figure 6.3.3 (page 104), which shows that the position of vessel Y at 0220 is more than five miles to the south of either collision point. Therefore, a fourth reconstruction was made, which would allow ship Y to collide with X within one mile of the collision position 12. For these events to occur it was assumed that Y kept course and speed until 0213, when ship X was at a distance of about 1.5 miles on her starboard bow. At that time, a course alteration to starboard with a turning rate of 45 degrees per minute was carried out. This reconstruction was started at 0150 and the plotting interval was 2 minutes. It has been reproduced in figure 6.3.4 (page 105). The collision occurred at 0218. An enlarged plotting, starting at 0212 and with a plotting interval of 30 seconds is shown in figure 6.3.5 (page 106). According to this test, at 0218 ship Z was at a distance of 1.9 miles from the collision point.

6.5 Case 4

The casualty was a collision between a cargo vessel of

1240 TDW, length 60 m (referred to as X), and a trawler of 200 TDW, with a length of 30 m (referred to as Y) which was following another trawler (referred to as Z). The collision occurred at about 0305 in position 55 43.0 N, 15 15.0 E in calm weather and dense fog. The following narrative is based on the statement given by vessel X.

Vessel X:

The day before the accident, Sandhammaren light house (55 23.0 N, 14 11.8 E) was passed at 2300 hours, at a distance of 2 miles, on course 057 degrees and speed 10 knots. The intention was to pass Utklippan light (55 57.2 N, 15 42.2 E) at a distance of 2 to 3 miles. Långagrund light buoy was passed 4 miles to port, the visibility being 2 to 3 miles. At 0130 the visibility decreased to 0.2 miles. At about 0255 the officer on duty observed on the radar screen two small echoes 5 degrees to starboard, distant 1.5 miles. The bearing did not change down to 1 mile. The range scale was changed to 2.5 miles but the echoes did not appear. When searching the vessels visually, one was sighted about 1 cable distant and 20 to 25 degrees to starboard showing a red light and turning to starboard. On board vessel X course was changed putting the auto-pilot hard-a-starboard, and the pitch was changed to zero. When the vessel was right ahead, a second ship was seen about 2 cables behind the first, showing a red light. The first ship passed 50 metres in front but the second could not be avoided and the collision occurred with an angle of impact of about 45 degrees. At the time of the collision the course was about 100 degrees and the speed 5 to 7 knots.

The events as stated by trawlers Y and Z resulted in the following narrative:

Ships Y and Z :

Vessel Y was behind Z on her starboard quarter, about 0.25 miles away. At 0055 Utklippan light was abeam at a distance of 6.2 miles. The course was 238, speed 10 knots, and the visibility nil. At about 0240 vessel Z observed an echo on the radar screen right ahead about 4 miles distance. When the distance was 3.2 miles the bearing remained unchanged. Z called Y on VHF and said that they had to turn to starboard. Course was changed to 270, 275 and 280 degrees, and when Y sighted the echo it was 3 miles away. At first the avoiding manoeuvre seemed to give effect but later, as the distance decreased, it seemed as if the echo had turned to port against the trawlers. Vessel Z turned more to starboard, followed by Y. At about 0300 hours, Z observed the two white lights of X and realized that she would pass astern. The visibility was about 200 metres. Z called again vessel Y and warned her about the situation. When Y sighted a white light on the port side about 50 metres apart, she reduced speed and turned more to starboard but it was too late. The collision occurred when the trawler was sailing at about 4 to 5 knots. The course was not known, although it had been altered from 238 degrees to starboard three times.

As usual, the first reconstruction in the radar simulator was made according to the events as stated by the parties. From the positions, courses and speeds given, the reconstruction was as shown in figure 6.4.1 (page 107). The plotting started at 0230, with one minute interval, and was stopped at 0305. The targets represent:

01 : vessel X

02 : vessel Z

03 : vessel Y

10 : position of collision

11, 12 and 13 : fixed targets one mile apart for scaling purposes.

It can be seen that the final position of vessel X at the time of the collision is about 0.6 miles northwest from the collision point reported, while vessel Y was at 0305 almost at the collision position. In the reconstruction, and following the statements of vessels Y and Z, the course alteration orders were assumed as shown in table 4. The course alterations were simulated at a turning rate of 60 degrees per minute.

The second reconstruction is represented by figure 6.4.2 (page 108). In this test, the position of X (now target 14), was shifted 0.6 miles to starboard in order to reach the collision position. A late course alteration to starboard was simulated at 30 degrees per minute. The plotting started at 0230 and the interval selected was one minute. Target 15 was included as the unknown echo detected by vessel Z and which gave origin to the course alteration which made the trawlers meet ship X.

An enlarged plotting is shown in figure 6.4.3 (page 109), in which vessel Z has been excluded in order to clarify the situation. This plotting started at 0250, the plotting interval was one minute, and the collision took place at 0306, 1.7 cables away from the reported position.

table 4

time	vessel Z	vessel Y
0245	270	
0247	275	270
0248	280	
0249		275
0251		280
0255	295	
0256		295
0305		330

6.6 Conclusion

The four casualties analysed are characterized by discrepancies in and/or lack of information and this is the case in a great number of investigations. A solution was tried to overcome these problems considering particular assumptions for each case. These analyses remain estimates as a result of the limited information available to the operator, who has to adjust certain parameters based on his own judgement to arrive at the best obtainable patern. Therefore, the solutions obtained, which form part of the report of the investigation, must be regarded as the most probable course of events.

In the next chapter, the possibility of automatic registration of data to solve the above mentioned problems is analysed.

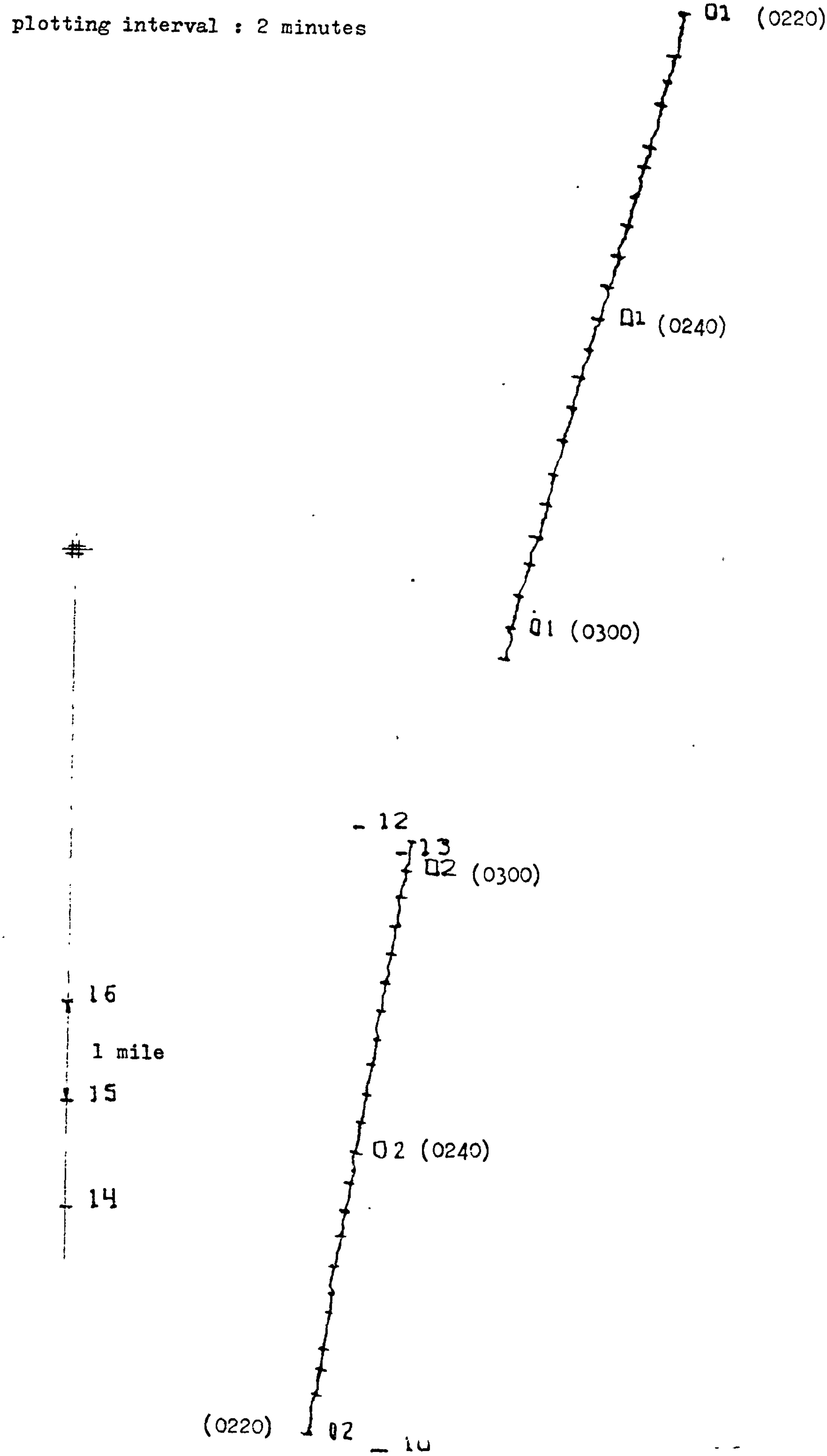

plotting interval : 2 minutes
01 (0220)
01 (0240)
01 (0300)
12
13
02 (0300)
16
1 mile
15
02 (0240)
14
(0220) 02

figure 6.1.1

plotting interval : 2 minutes

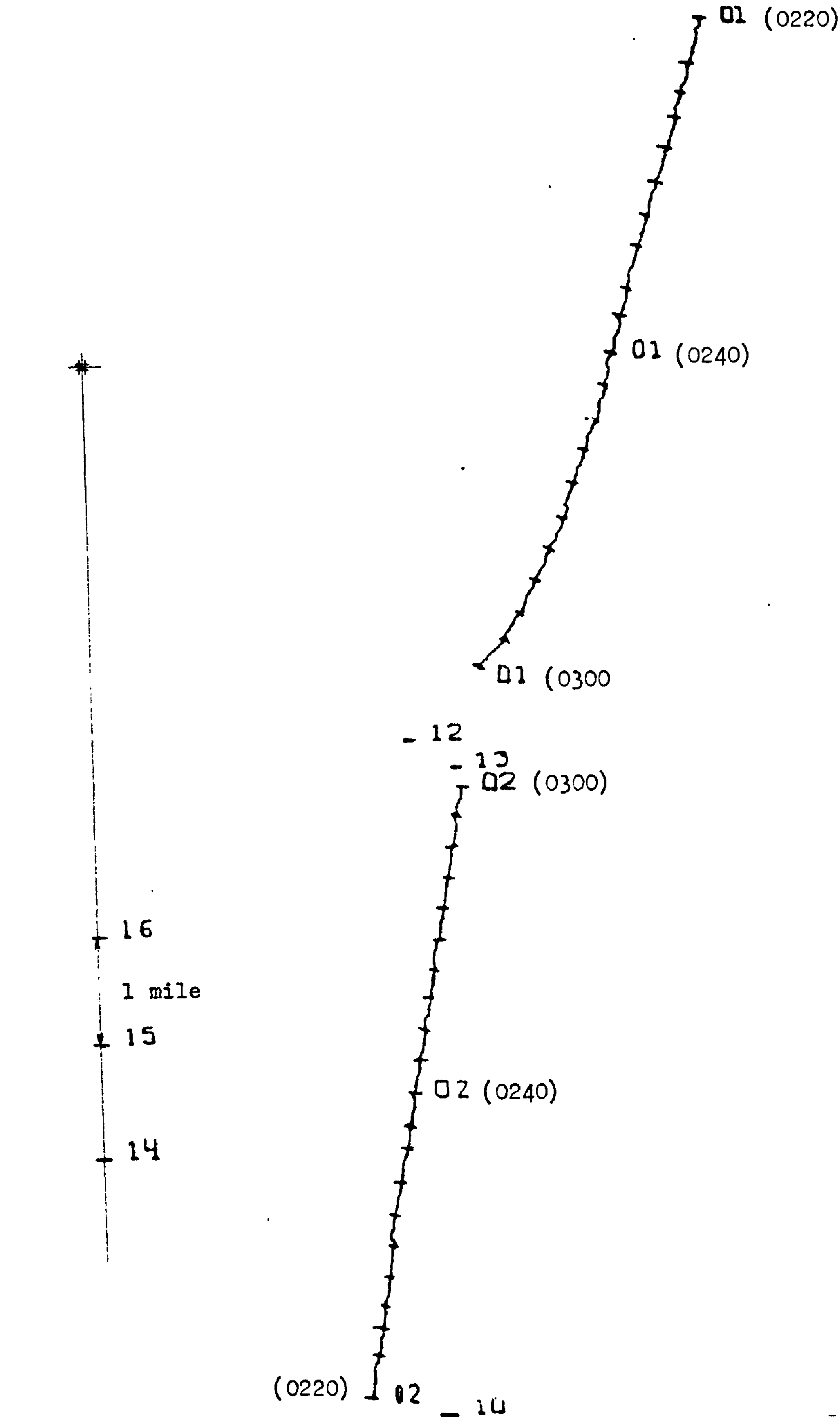


figure 6.1.2

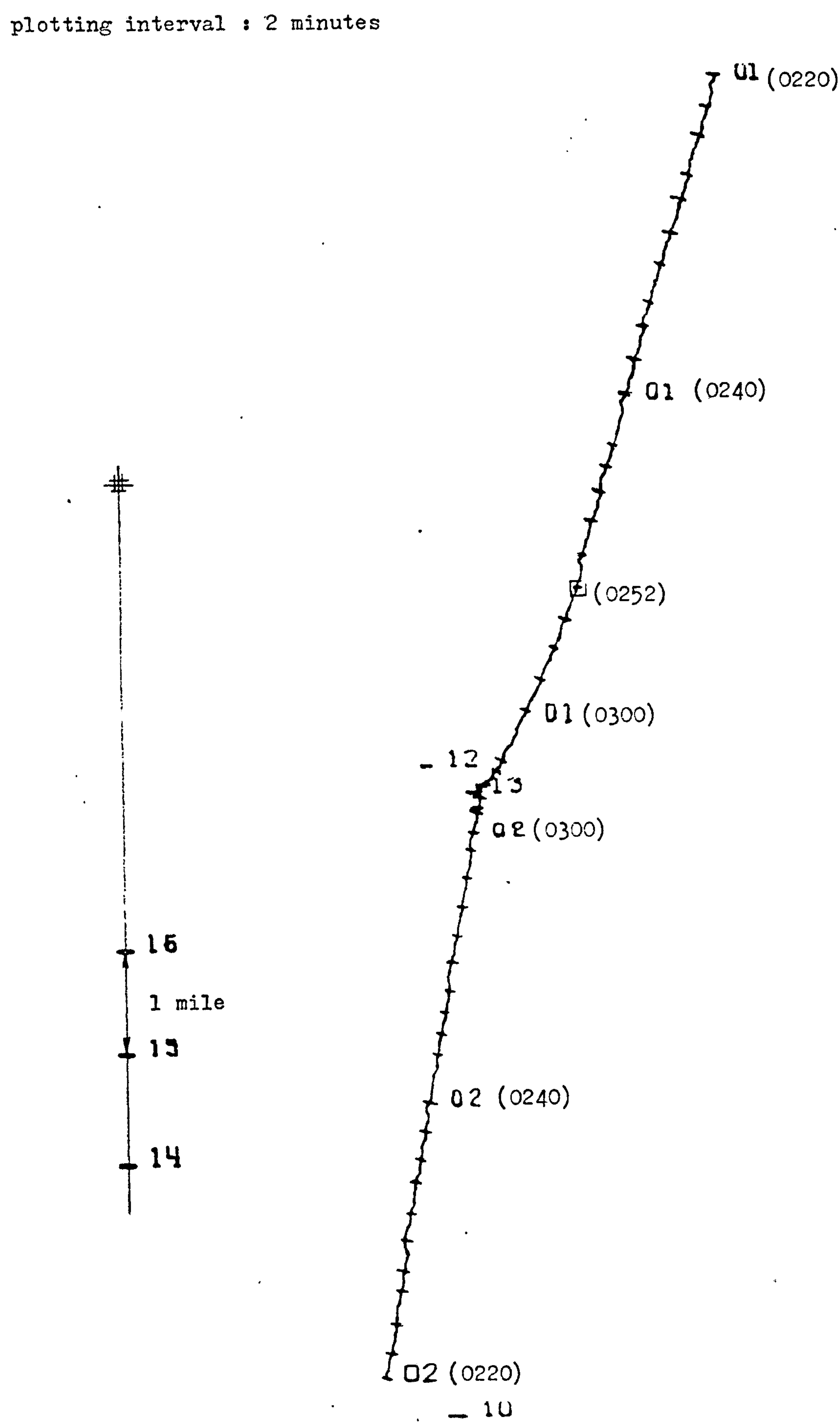

plotting interval : 2 minutes
01 (0220)
01 (0240)
(0252)
01 (0300)
12
13
02 (0300)
16
1 mile
13
14
02 (0240)
02 (0220)
10

figure 6.1.3

plotting interval: 1 minute

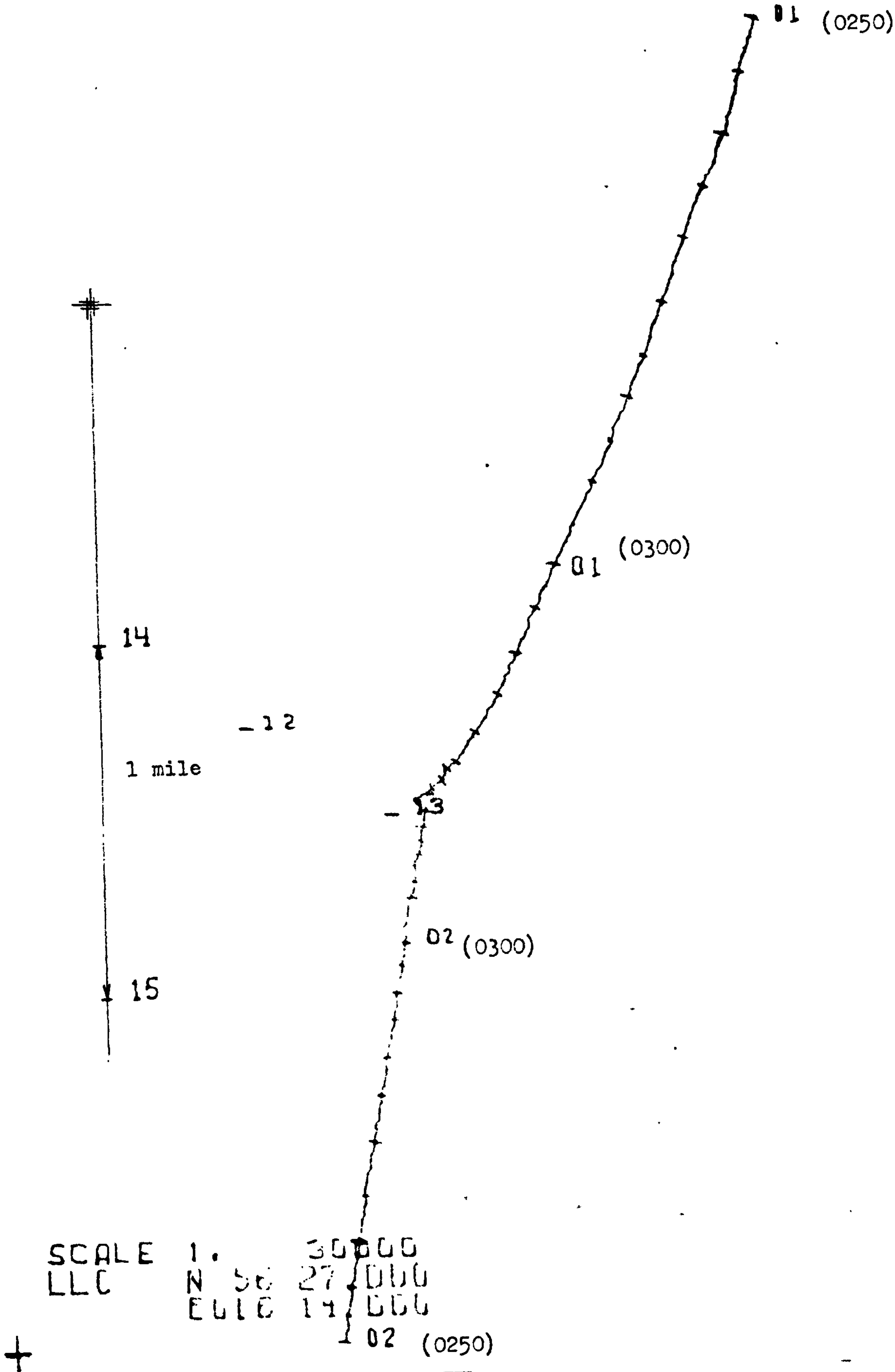
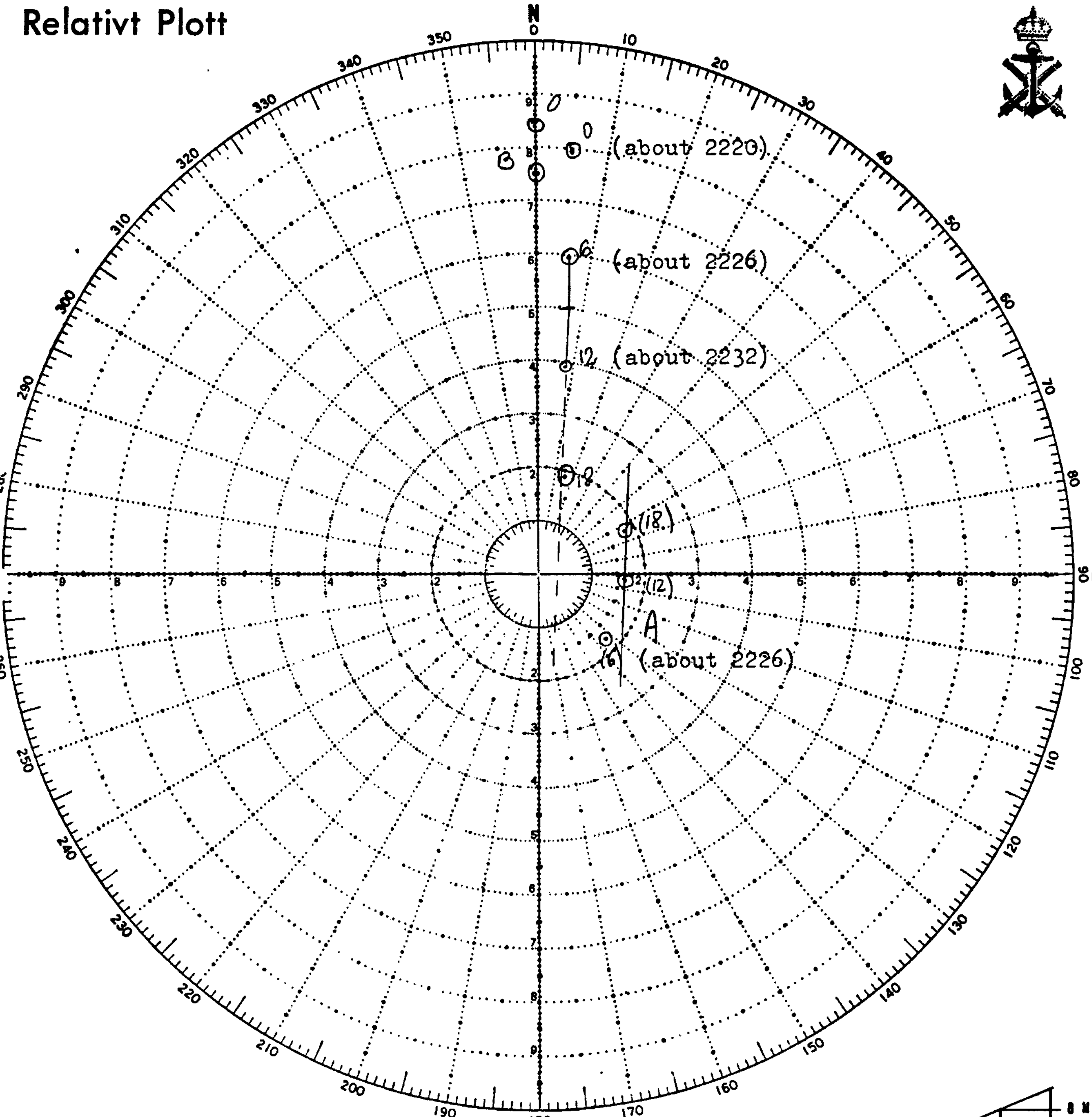
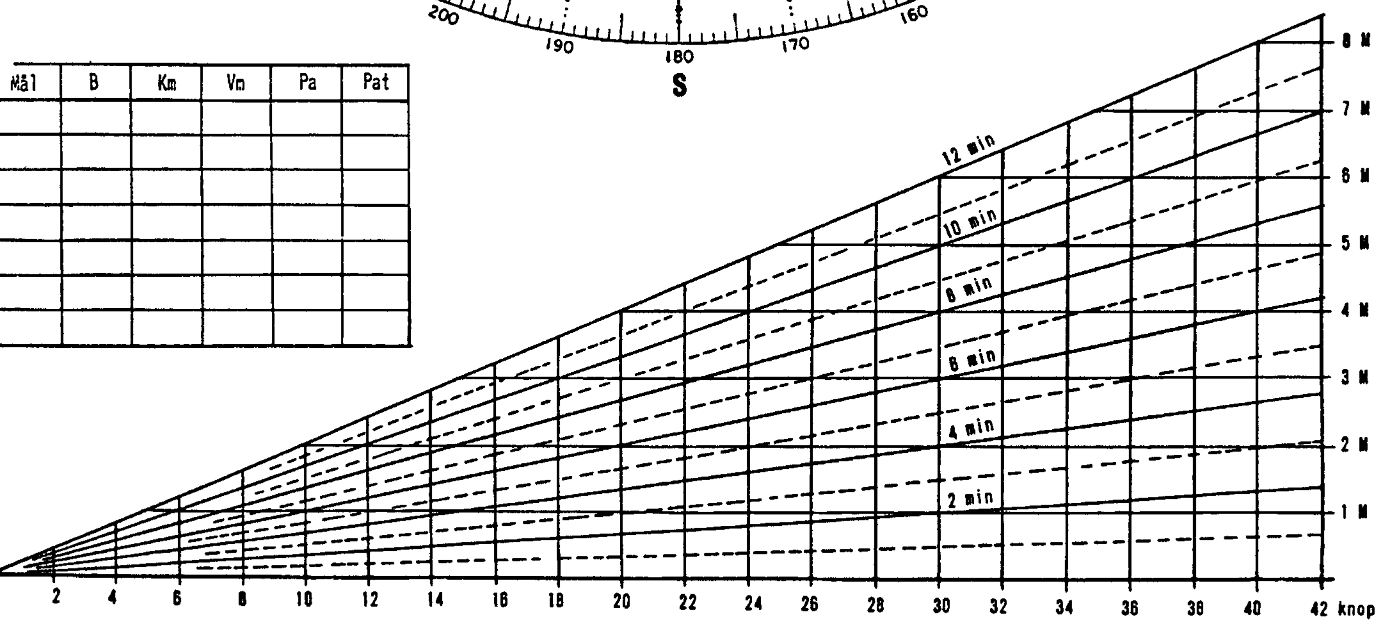


figure 6.1.4

Relativt Plott



Mål	B	Km	Vm	Pa	Pat



1107-263001

figure 6.2.1

plotting interval : 2 minutes

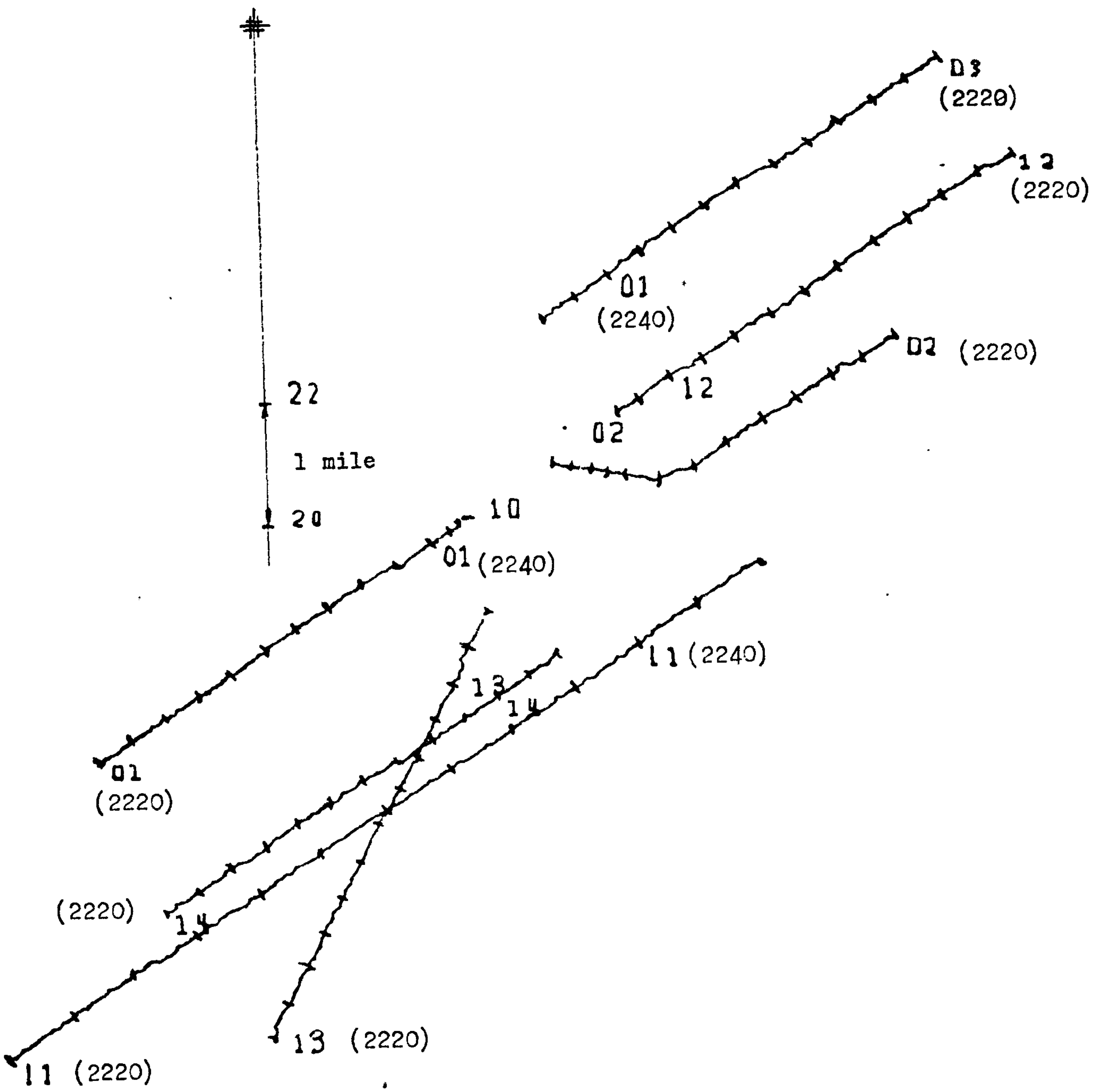


figure 6.2.2

.00000
20.000
25.000

plotting interval : 2 minutes

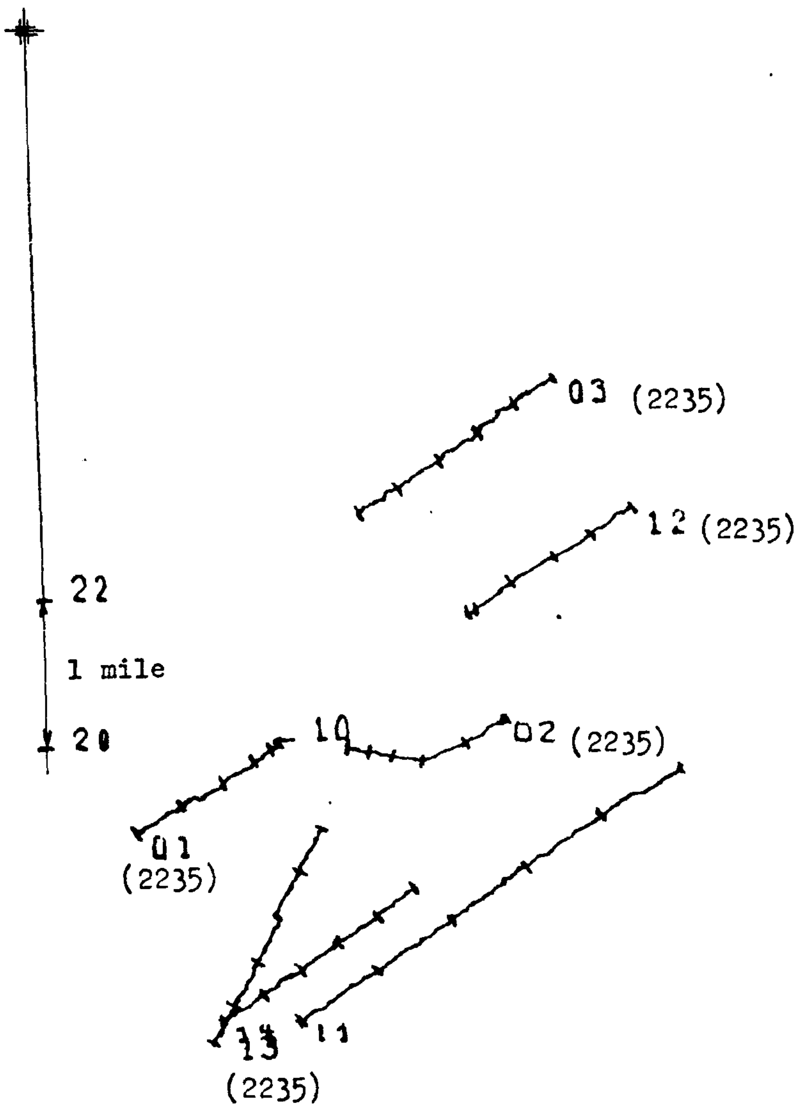
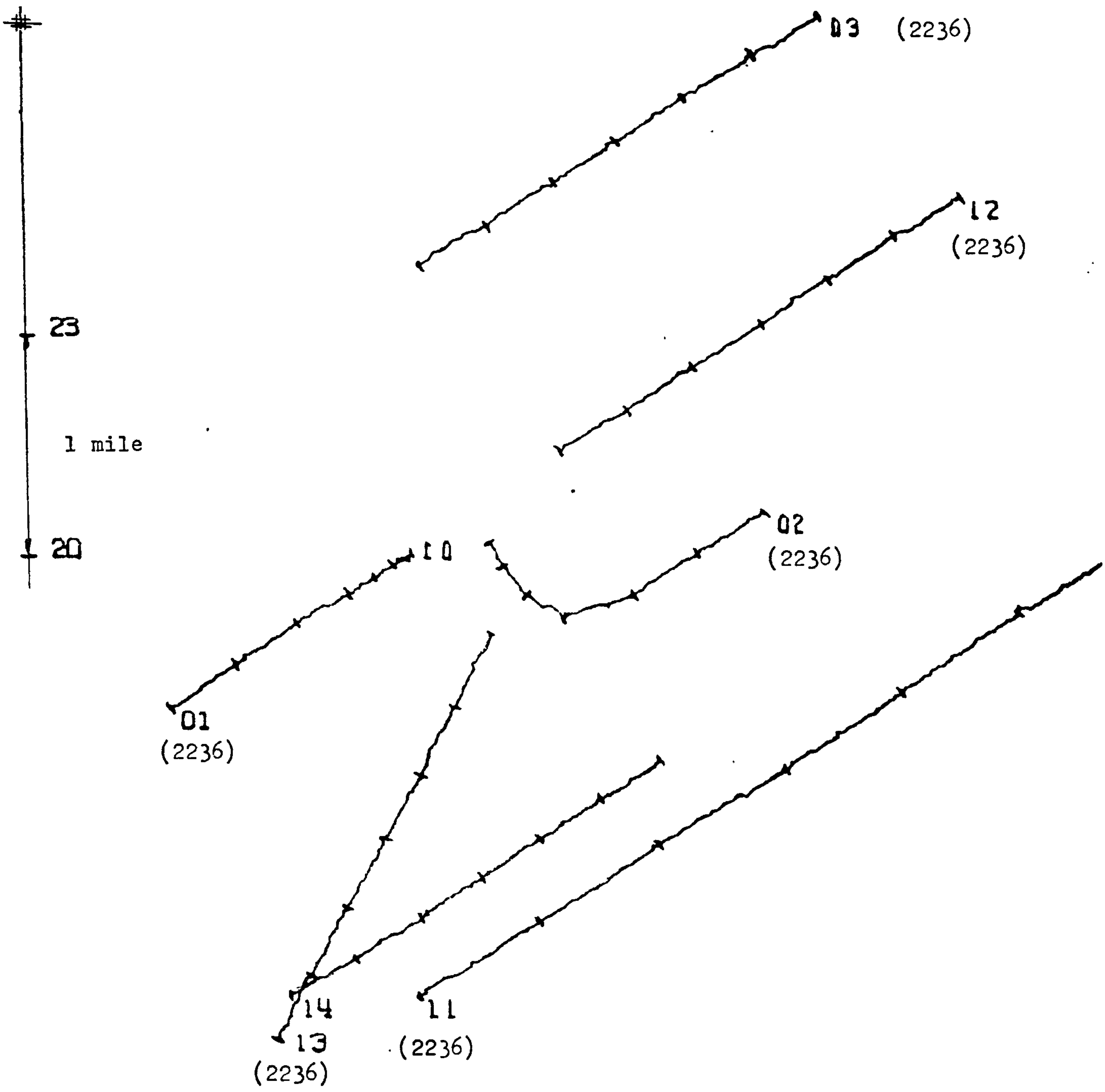


figure 6.2.3

plotting interval : 2 minutes



SCALE 1. 50000
LLC N 55 24.000
E014 35.000

figure 6.2.4

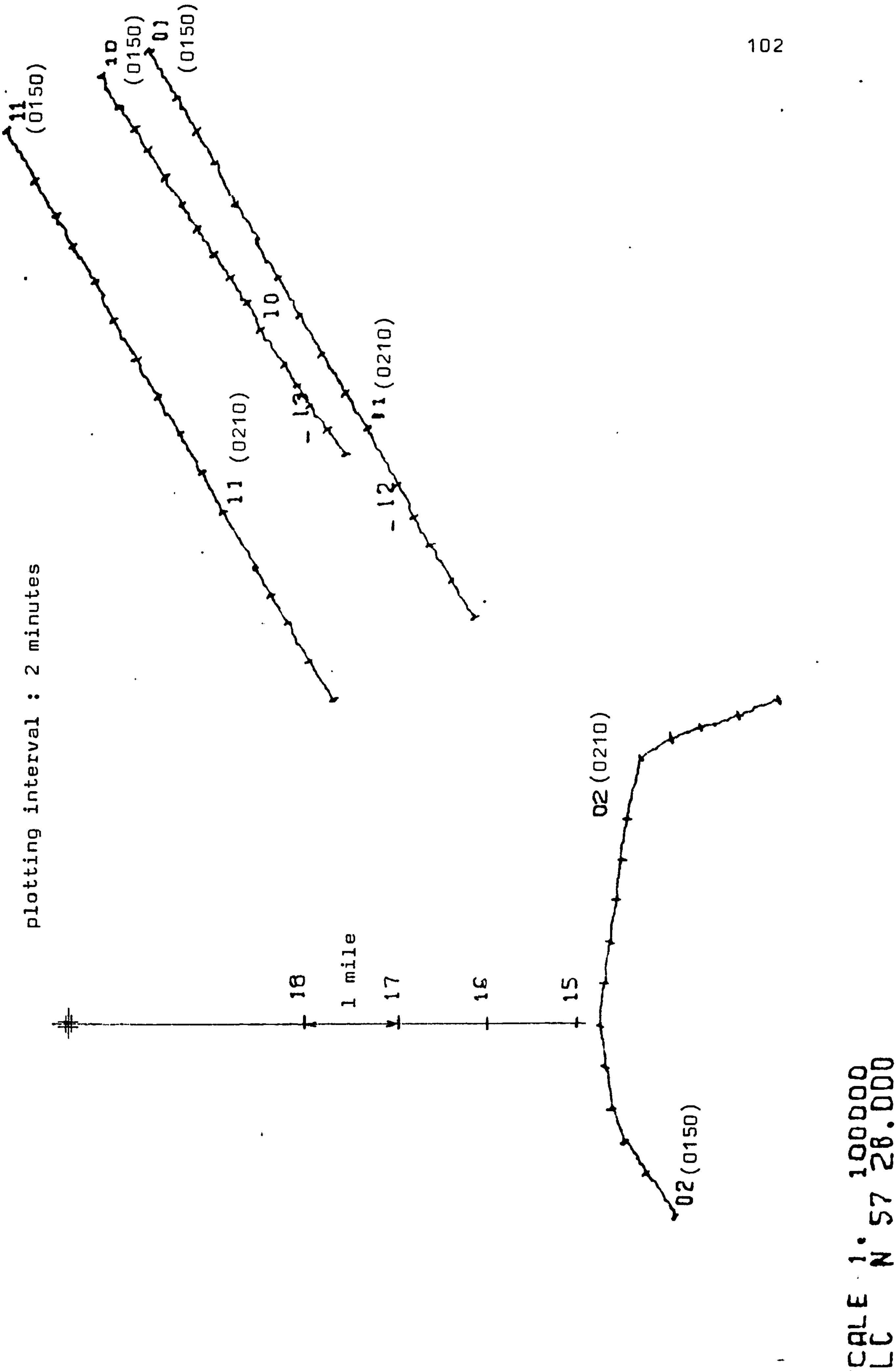

plotting interval : 2 minutes
1 mile
18
17
16
15
11 (0150)
10 (0150)
01 (0150)
11 (0210)
10
13
01 (0210)
12
02 (0210)
02 (0150)
SCALE 1. 100000
LLC N 57 28.000
E009 10.000

figure 6.3.1

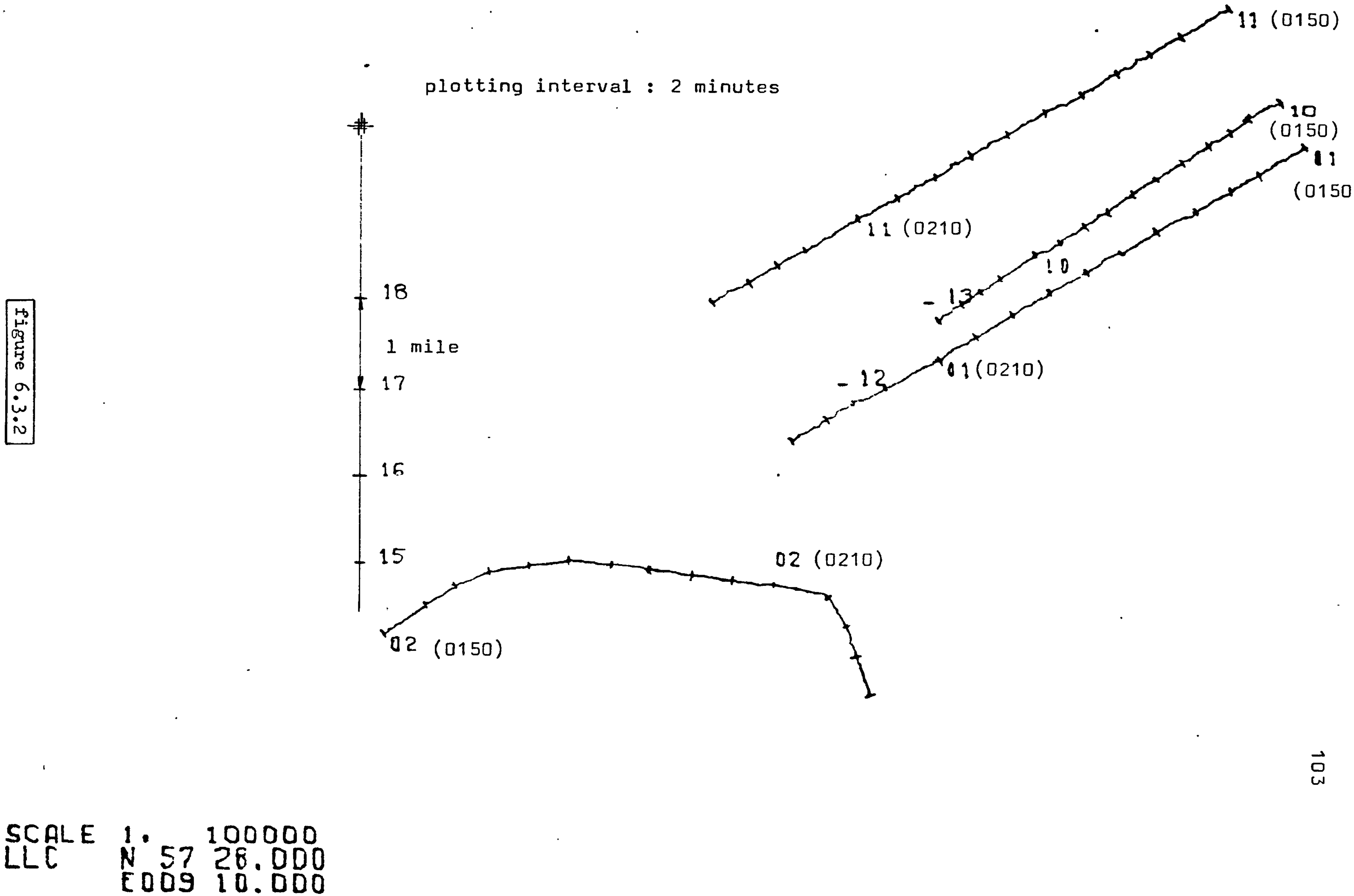

plotting interval : 2 minutes
11 (0150)
10 (0150)
11 (0150)
11 (0210)
10
-13
-12
01(0210)
18
1 mile
17
16
15
02 (0210)
02 (0150)
SCALE 1. 100000
LLC N 57 26.000
E009 10.000

figure 6.3.2

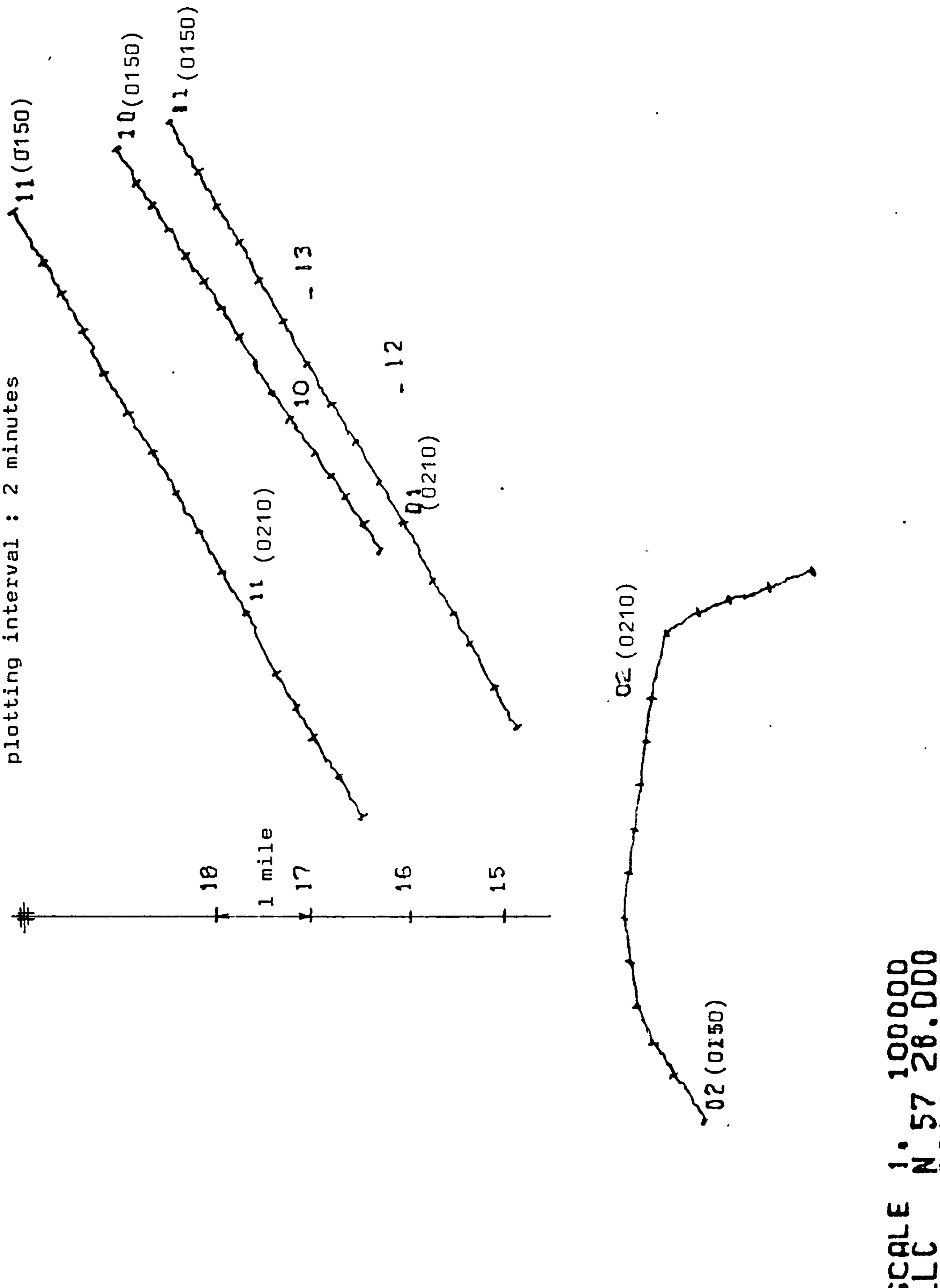

plotting interval : 2 minutes
11(0150)
10(0150)
11(0150)
- 13
- 12
10
01 (0210)
11 (0210)
02 (0210)
02 (0150)
18
1 mile
17
16
15
SCALE 1. 100000
LLC N 57 28.000
E009 10.000

figure 6.3.3

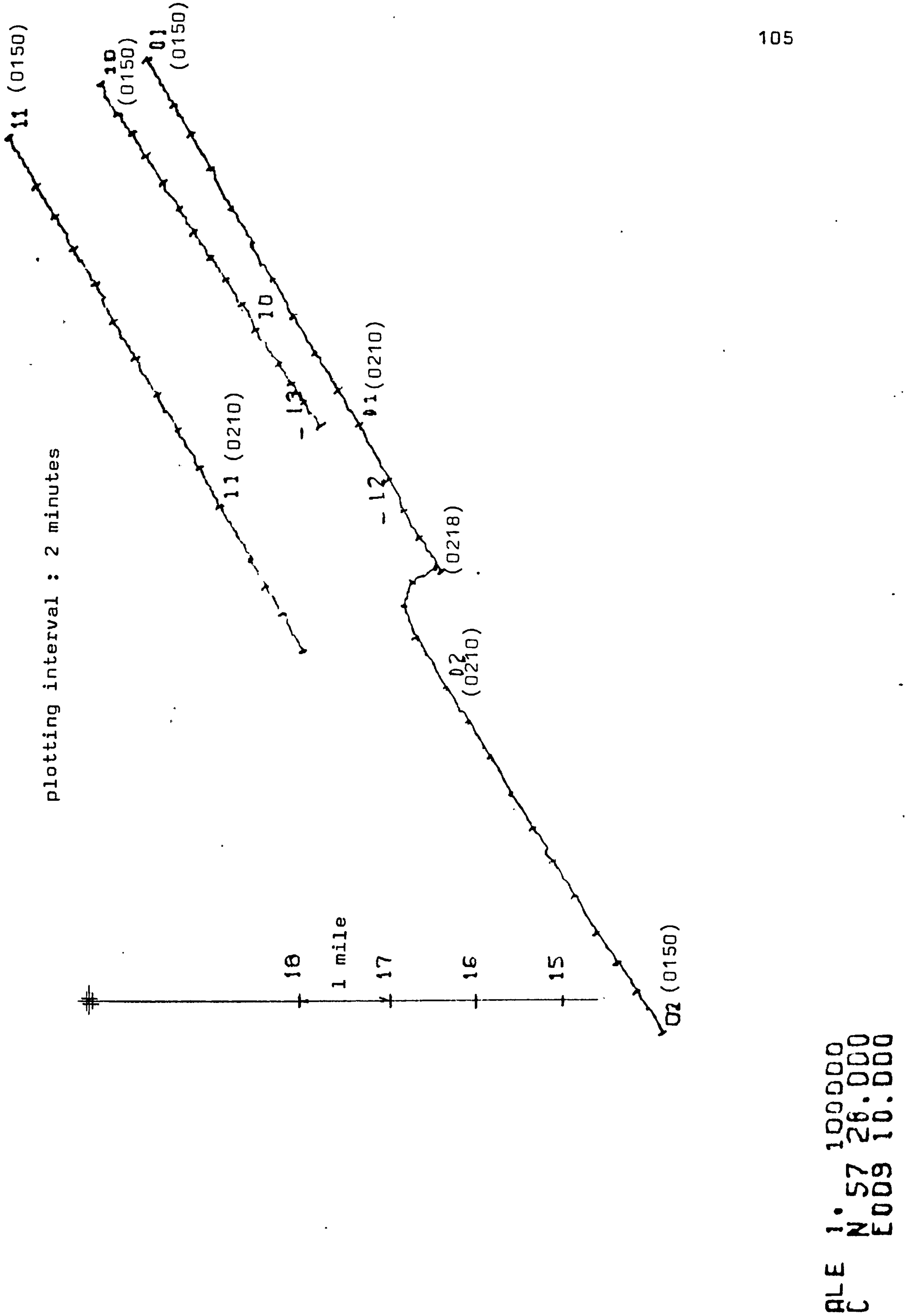

plotting interval : 2 minutes
11 (0150)
10 (0150)
01 (0150)
10
01(0210)
11 (0210)
-13
-12
(0218)
02 (0210)
02 (0150)
18
1 mile
17
16
15
SCALE 1: 100000
LLC N 57 26.000
E009 10.000

figure 6.3.4

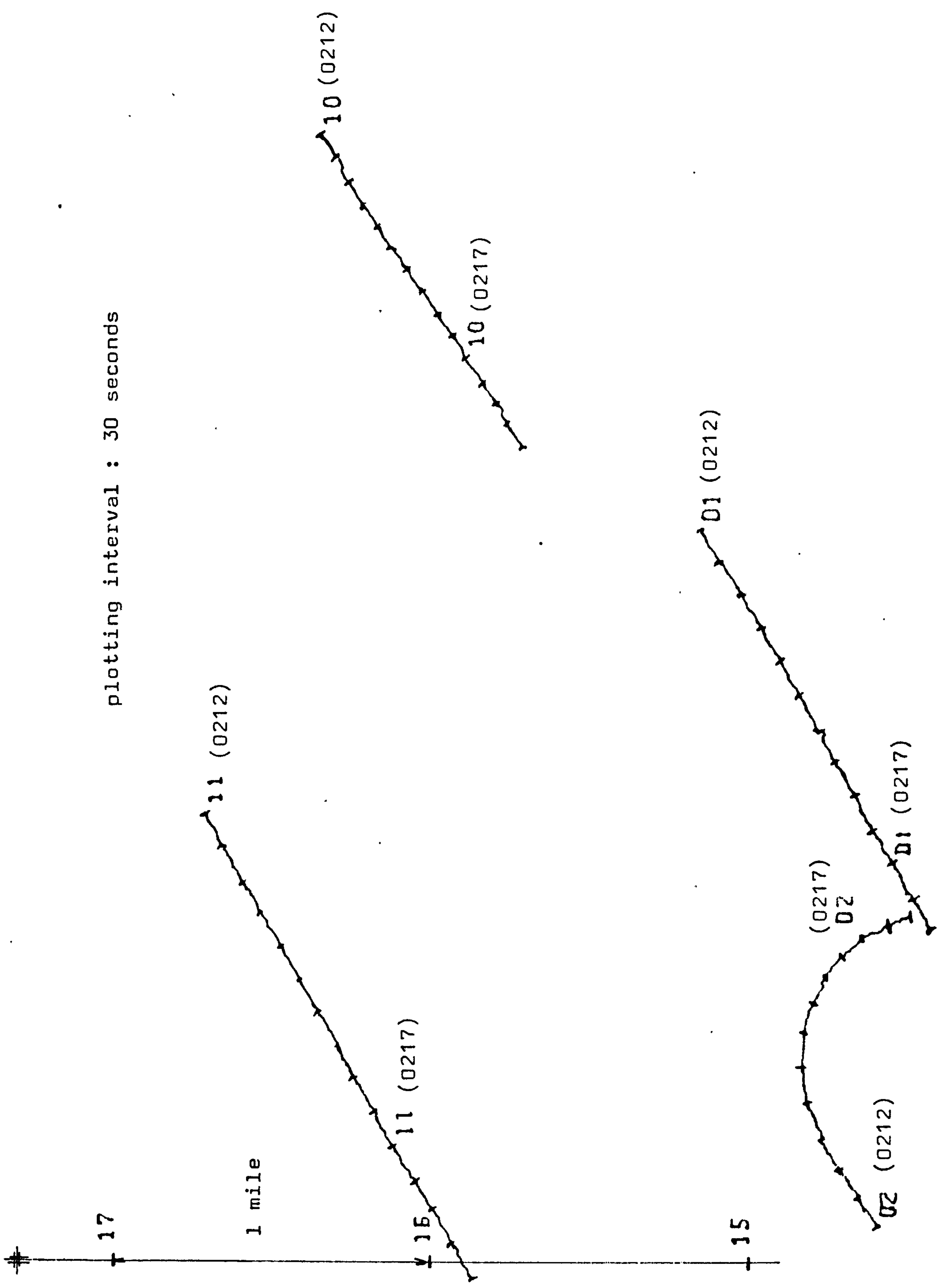

plotting interval : 30 seconds
10 (0212)
10 (0217)
D1 (0212)
D1 (0217)
11 (0212)
11 (0217)
D2 (0217)
D2 (0212)
1 mile
17
16
15

figure 6.3.5

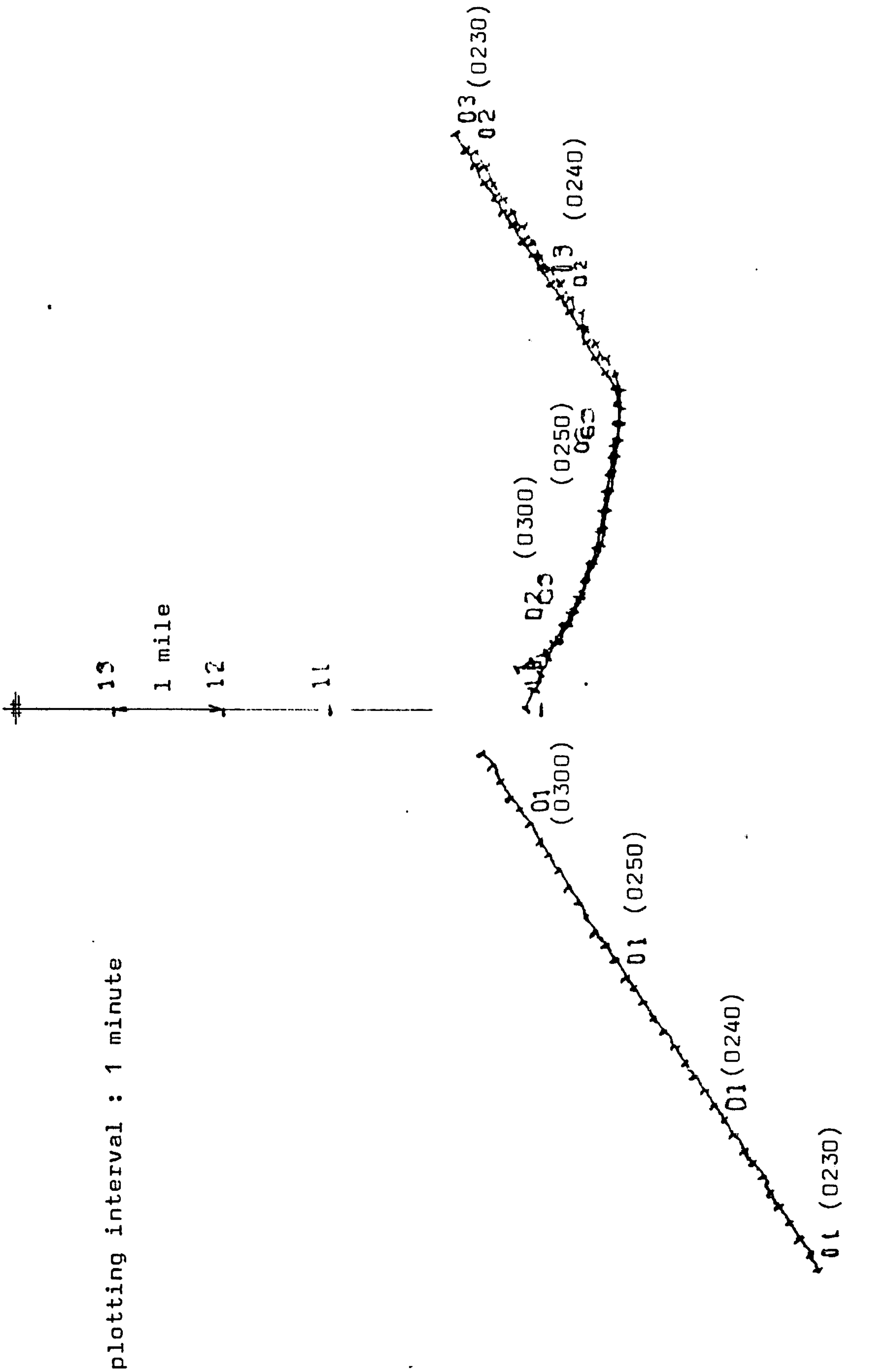
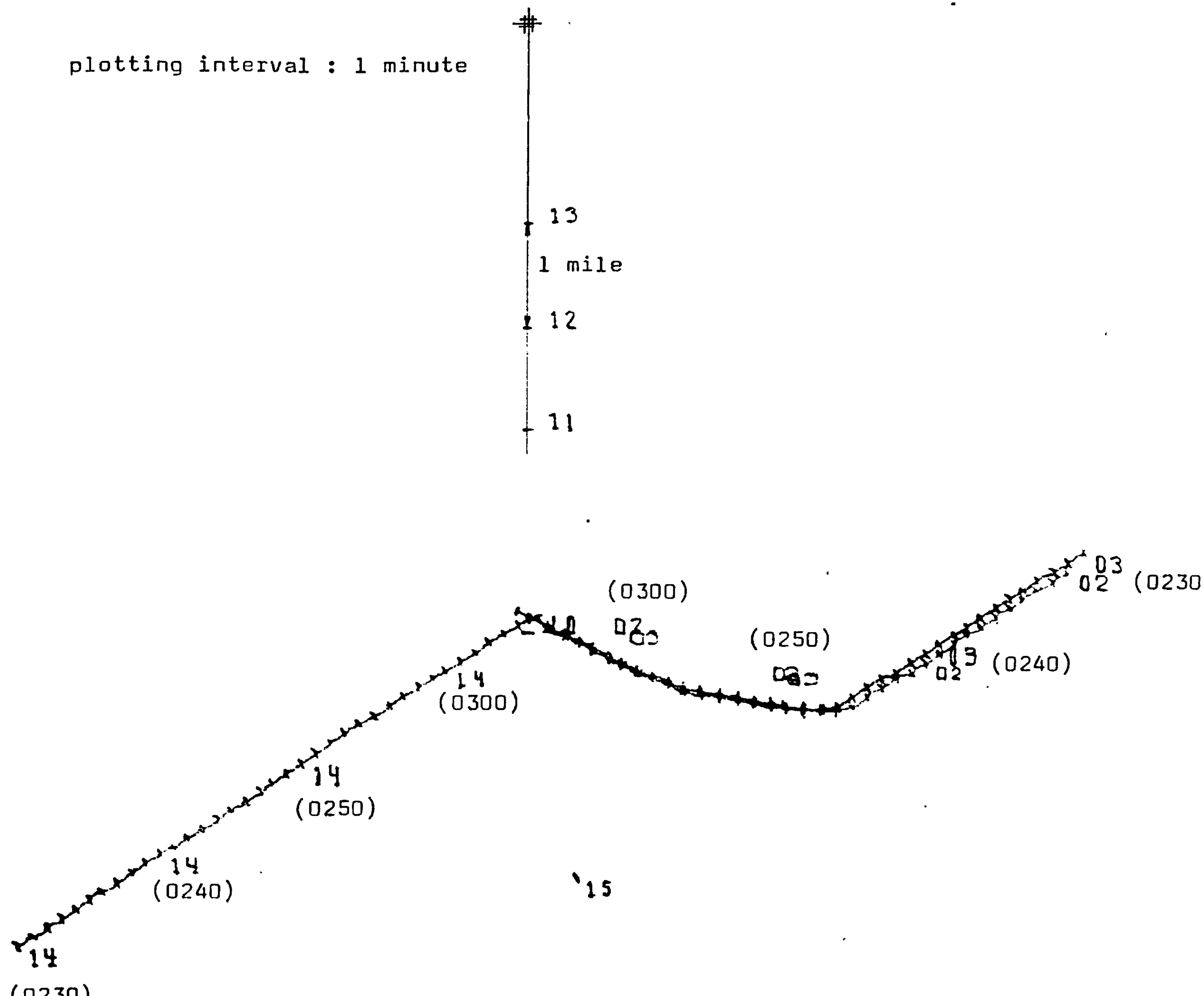
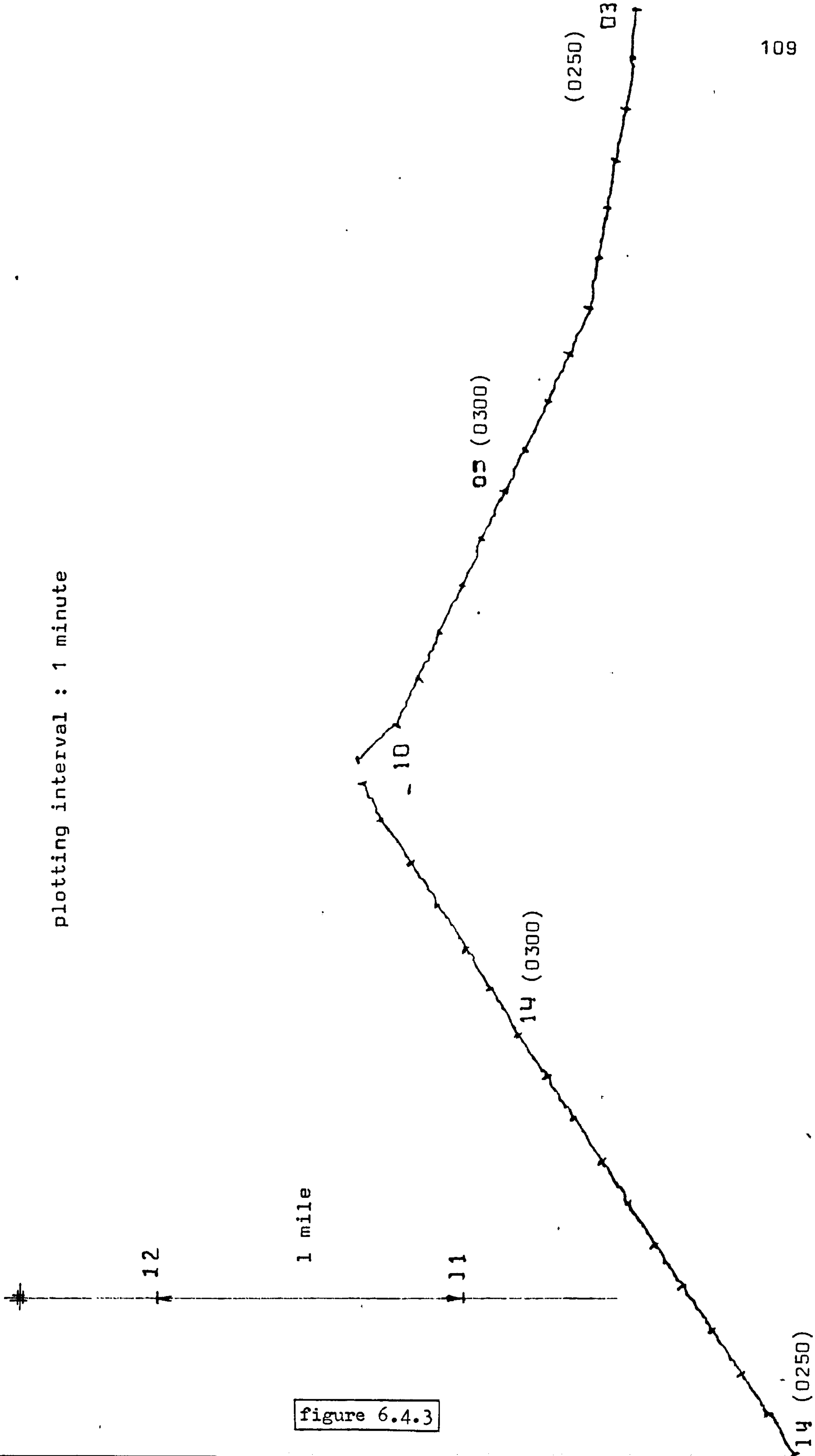

plotting interval : 1 minute
1 mile
13
12
11
03 (0230)
02
(0240)
03
02
(0250)
(0300)
02
01
(0300)
01 (0250)
01 (0240)
01 (0230)

figure 6.4.1



plotting interval : 1 minute
13
1 mile
12
11
14
(0230)
14
(0240)
14
(0250)
14
(0300)
15
(0300)
02
(0250)
03
02
(0240)
03
02
(0230)

figure 6.4.2



plotting interval : 1 minute
1 mile
12
11
10
03
03 (0300)
(0250)
14 (0300)
14 (0250)

figure 6.4.3

CHAPTER 7

DATA ACQUISITION AND RECORDING UNITS ON BOARD SHIPS

7.1 Introduction

The information which investigators are able to collect after a casualty occurred is in many cases insufficient and imprecise. The cases analysed in chapter 6 reflect this situation in the case of collisions at sea, and also show the kind of assumptions which have to be made by the operator of the simulator, not only filling in the information gaps but also deviating from the original statements, in order to produce the collision. As a matter of fact, the use of radar simulators is proposed as a valuable tool to investigate collision cases especially when conflicts and controversies arise during the reconstruction, because of the possibility to present a complete picture of the situation and introduce different modifications in a relatively short time. To facilitate the work, investigators might be instructed to try and obtain more precise and quantified information, bearing in mind the type of information required for the purpose of the investigation. A question, however, which remains to be answered is the degree of confidence which can be placed on statements that are not backed up by clear evidence.

7.2 Data recording

An obvious solution to overcome this problem is to complement witnesses statements with registered operational data, adequately protected against destruction. The registration of certain information is in fact done on board ships and ashore in different ways, either manually, automatically or semi-automatically. In this context one can easily list the following:

(a) manually:

bridge log book

navigation chart

engine room log book

(b) automatically or semi-automatically:

course recorder

engine order recorder

electronic position fixing recorder

echosounder graphs

VTS information recorder

radar video recorder

The situation, however, is rather chaotic as the recordings mentioned in (a) are seldom completed when events actually take place, and those listed in (b) are neither fitted in all ships nor always used properly. On the other hand, nothing prevents those recorders and their contents from being destroyed, either accidentally or intentionally, forged, lost, or simply not disclosed, should a casualty happen.

7.3 Automatic data acquisition and recording units

In view of the lack of standardization in this field and the need for accurate information, consideration should be given to the installation on board ships of automatic data acquisition and recording units to supply reliable and complete information about the course of events prior to a casualty. Such devices will be referred to with the abbreviate denomination of "data recorders" in this project from now on. As those units have only been tested experimentally on a limited basis, there is no practical experience available to demonstrate that their use will lead to an increased safety at sea. However, in the process of safety oriented casualty investigations a large amount of data which nowadays is missing or unreliable, could be supplied by those data recorders, which suggests the desirability of their installation on board ships. In this context, the experience gained through many years of use of flight recorders and the large number of investigations carried out in aeroplane accidents with the help of those recorders should not be neglected.

In this project, the question of data recorders on board ships is analysed within the framework of casualty investigations, that is after accidents have occurred. However, the installation of recording devices might also result in improved safety as a preventive measure, inducing officers to safer practices if they are aware of the automatic recording of their actions. The discussion of this aspect is beyond the scope of the project.

The possibility of installing data recorders on board ships leads to the next question, that is at which level the possibilities should be discussed and evaluated. It can be expected that seafarers and shipowners will object to the introduction of such devices because of the vast consequences in the marine industry. An irresponsible handling of the information collected can be feared if no well established legislation is set out. Therefore, regardless of the studies carried out by different governments and classification societies, such an important matter should receive consideration in international forums. In this context, it can be mentioned that the problem is dealt with in IMO by the Sub-committee on Safety of Navigation.

Before introducing data recorders as an international requirement, a number of aspects must be elucidated, which will be briefly analysed.

7.3.1 Technical feasibility

Nothing indicates that insoluble problems might preclude the development, production and installation of such devices on board. In fact, prototype data recorders are actually under test. However, the complexity of the recorders and their costs will depend on the type of data required. The lack of standardization of shipborne equipment represents a disadvantage which has to be considered when interfacing the recording device with the different sources of data.

7.3.2 Objectives

It is necessary to define which are the objectives for installing the recorders on board ships. From the definition, it is clear that the reason for having such devices is to provide a way to save operational data on board the ship. This information may then be used as a basis for analysis whenever that is thought to be necessary. The question are, should the use of recorded data be restricted to certain occurrences, who should have access to the data, and should it also be used under normal operation of the ship. The objectives will influence the type and amount of data to be recorded and possibly have legal consecuences as well.

7.3.3 Data to be registered

The information to be recorded may be limited to that necessary to establish the course of events prior to a collision or grounding, or may be extended to include a large number of parameters covering all aspects of the operation of the ship. This point is closely linked to the objectives mentioned in paragraph 7.3.2.

For the type of analysis which is dealt with in the context of this project, it is required to have data providing an adequate picture of the ship's movement and environmental situation prior to a collision. Bearing in mind, however, that the reconstruction should not only be made to establish the course of events but also to determine cause relationship, additional information is required. The following data acquired and recorded could form in principle an adequate analysis basis :

- time
- position
- course
- speed
- engine orders
- main engine data
- radar video data
- speech recording
- ship's technical data

The voice recording listed refers to communications on the bridge related to the handling of the ship, that is orders and commands, and radio traffic.

7.3.4 Protection against damage and recovery

In the event of damage to the ship, the question of protection of the information contained in the data recorder must be considered. The data should also be protected against unauthorized manipulation. Not less important is the recovery of the device if as a result of the casualty the ship sinks.

7.3.5 Recording duration

As any other recording device, the data recorder will have a limited memory capacity. It is not conceivable that all the data accumulated during a long sea passage can be recorded and therefore a minimum memory loop has to be specified in order to retrieve enough data to obtain valuable information within the established objectives. The memory capacity is closely linked with the sampling rate of the recorder. A means to reset the system at the end of an uneventful journey or for other reasons has to be accounted for.

7.3.6 Testing and monitoring

A data recorder should include the possibility to test the operational status of the device as well as a way to monitor that valid data is being recorded, without disturbing the normal operation of the unit.

7.3.7 Scope of application

Should the use of data recorders become a requirement under international law, certainly certain ships will be exempted, as it happens with the regulations of almost all international legal instruments. Therefore, agreement has to be reached upon the applicable exemptions and limitations.

7.3.8 Juridical aspects

As it was considered in paragraph 7.3.2, a careful analysis should be made of the legal aspects of using and operating the data recorders on board ships because the information obtained from those units will constitute material evidence. Privileges attached to this evidence and in what way it can be used in case of legal action are to be clearly established and later included in the legislation of each country.

7.4 Positioning systems

One of the key aspects of the installation of data recorders on board ships as far as navigation monitoring is concerned, is the availability of positioning data. So far, there is no system available which provides accurate and continuous position on a world wide basis, which in itself represents an important limitation. In this field, a number of global positioning systems are under development and will become operational in the near future for use on board merchant ships. Those systems will provide all weather, world wide continuous position with a minimum accuracy of 0.1 miles (R95) for commercial use. Therefore, it can be expected that if data recorders are to become mandatory for world wide use and the position of the ship is one of the parameters to be registered, they would only be introduced after those positioning systems are put into service and used on board merchant ships.

7.5 Conclusion

There are strong arguments in favour of the use of data recorders on board ships within the framework of safety at sea. The rapid technological advancements in the marine field now makes the development of these recorders possible, which will probably become a familiar device in the not so far future. Their use will represent a major step in the solution of problems connected to the investigation of accidents to ships and determination of cause relationship. However, they represent an interference on board which will obviously be resisted, considering it as a threat to freedom of action and privacy. Also, the installation of such sophisticated devices on board will certainly involve extra expenditures for the shipowner.

Maritime administrators now have the opportunity to anticipate the numerous problems which will arise and take steps at an early stage at international level to ensure the proper use of the recorders together with the information provided.

CHAPTER 8

LEGAL ASPECTS

8.1 Introduction

In this project, the reconstruction of collision cases at sea with the help of radar simulators has been analysed basically in the context of marine casualty investigation. Therefore the reconstruction work will become an integral part of the investigation procedure conducted by a governmental agency, which has been dealt with in chapter 2. Certainly, a collision might also be subject to test in the simulator at request of the solicitor of one or both of the parties to the casualty. In any case, a reconstruction is one of the wheels in a mechanism which works under the umbrella of the legislation established by each country. Therefore, the operator of the simulator should be aware of the legal implications of the process.

8.2 Non-official settlement of disputes

In this case, the aim of the reconstruction work will be to strengthen the position of a party in a civil liability dispute and/or penal action in court. As the purpose of the solicitor's work is to protect the interests of his client, it can be expected that being such the case, there will be a bias in favor of one of the parties. If the results are unfavourable to the party represented, the reconstruction will of course be stopped and not mentioned any more. If, on the other hand, the findings are favourable, the lawyer will try to utilize them as evidence. The person responsible for the reconstruction work will probably be subject to cross-examination by the representative of the opposing party, who will try to discredit the evidence presented. Therefore, any assumption made which can not be clarified or explained with the help of clear facts will be utilized as a means to destroy the credibility of the results obtained. This question is particularly important if the case is taken to court.

8.3 Official inquiries

The situation is generally of a different nature if the work in the simulator forms part of an inquiry carried out by the administration. The operator of the simulator may form part of the staff of the investigating authority, in which case he has a good understanding of the investigation process and its legal aspects. More than once, however, his services may be required only occasionally as a specialist both in navigational and radar simulation matters. Therefore, he might not be familiarized with the general procedures. A thorough knowledge of the particular legislation and investigating practices and procedures in use will be of great benefit both for the operation of the simulator and for the success of the whole process. There are several points of particular interest in this context which will be elaborated in the following below.

8.3.1 The objective of the investigation

As analysed in chapter 2, the objectives of the investigation vary greatly from country to country and can be classified as follows:

(a) to determine cause relationship
(b) to recommend safety measures
(c) to establish fault and take disciplinary action
(d) to apportion liability

Regardless of the advantages or disadvantages of the system adopted, it must be known whether the investigation is solely oriented to determine causes and make appropriate recommendations or to determine blame and impose penalties, or a combination of both. Investigators must bear in mind that for the purpose of taking disciplinary action, where the rights of individuals are involved, the evidences presented must meet standards far beyond those required to recommend safety measures. On the other hand, an impartial investigation purely oriented to safety improvement may result in a report from which fault gives rise to disciplinary action and civil liability, even if these questions are dealt with by another court. This fact should not interfere with the investigation procedure.

8.3.2 Status and role of interested parties

In any casualty investigation a number of parties are involved for various reasons. Parties include not only the persons directly connected to the accident but also shipowners, underwriters and regulatory bodies, among others. Whether the different parties have a status of full participants, partial participants or observers, together with their role during the many stages of the investigation has to be established in the legislation. The operator of the simulator is particularly interested in the degree of participation of those parties during the tests as well as the documentation and reports which can be released. He must also know if the parties may be accompanied or represented by a councelor, and their role during witnesses' interviews.

8.3.3 Powers and jurisdiction of the investigating authority

In order to conduct the inquiry, designated officers must be given specific powers by way of appropriate legislation. Those powers refer to detention of ships and/or wrecks, inspection of premises, seizure of documentation and other evidence, test of equipment and examination of witnesses. Under certain legislations the testimonies of witnesses must be taken under oath and provisions about electronic recording of the interviews are also included.

8.3.4 Privilege attached to evidence obtained

The investigator must be aware of the confidentiality (or non confidentiality) of the evidence obtained.

This point has been analysed in chapter 2 with respect to the possible advantages or disadvantages of the different ways in which this matter is treated under various legislations. For the investigator it is important to know to what extent the evidences obtained can be used in subsequent legal proceedings. The same applies to any recording obtained either from a VTS, a coast radio station or the bridge of the ship. The use of names of ships and individuals involved in the accident together with any other means of identification when issuing the casualty report must also be considered in the context of the confidentiality status.

8.4 Conclusion

The aforesaid aspects underline the basic legal matters to be taken into consideration, but do not exclude other specific regulations which might be found in a particular legislation. The operator of a radar simulator who may take part in an investigation process, either as a member or assesor of the inquiry board or as a private consultant, will inevitably be involved in the legal proceedings and therefore his understanding of the problems is as important as his professional expertise in the field of the investigation.

CHAPTER 9

SUMMARY AND CONCLUSIONS

The purpose of this work has been to establish the possible contributions of radar simulators to the field of investigation of marine casualties, bearing in mind the objective of safety promotion at sea. This has been done by analysing the suitability of the simulators for the reconstruction of collisions and groundings. In this context, it has been considered necessary to review both the marine casualty investigation process and the main characteristics of radar simulators before linking the two elements.

The first element, the investigation, has been recognized as a necessary procedure if the actual sequence of events prior to a casualty as well as the actions taken after the accident occurred are to be known, even when the results do not represent a guarantee of absolute certainty of the findings. Apart from that,the objectives of the investigation have been classified, ranging from purely safety oriented objectives to those solely focused on establishing blame. Certainly, both are extremes and generally the legislation adopted by different countries will be based on objectives which are somewhere in between.

As a result of an accident, heavy losses will normally occur and this is especially the case in collissions at sea and groundings. Procedures aimed at establishing fault and apportioning liability will be conducted. Certain cases also require disciplinary action against individuals. However, the importance of analysing a case as the key to the proposal of safety measures has been stressed. Whilst a penal action and/or the settlement of a dispute deal with a particular case after it has happened, adequate safety measures taken as a consequence of the investigation of an accident work as a preventive action which can avoid the occurrence of similar casualties in the future. The recommendation of measures is only the result of a study which starts by trying to establish the chain of events based on the information available.

The second element of this study, the radar simulator, has been subject to an analysis aimed at establishing its capabilities as well as its limitations. It is unfortunate that no internationally accepted rules exist to determine the minimum characteristics and specifications which a radar simulator must fulfil to be considered as such, particularly as it has been recommended elsewhere that courses should be conducted in that type of simulators, which are nowadays a common training tool in a great number of educational institutes. However, by its own nature it was recognized that a radar simulator must reproduce ships' tracks as a result of their response to engine and helm orders as well as to a number of environmental influences, and in addition provide simulated radar pictures of the situation to the radar displays installed on the bridges.

Any simulator consists of a hardware and a built in programme to carry out the simulation, which may restrict the type of cases to be analysed. The minimum specifications of a radar simulator in order to be used to reconstruct a case of collision in deep waters have been considered.

It has been analysed that the need to reconstruct the path followed by a ship arises when a case of collision or grounding is under investigation, as a first step to determine the cause or causes of the accident. The better the course of events is ascertained, the more likely the cause or causes of the casualty can be established. Therefore, the aforesaid reconstruction is the link between the investigation process, in which such reconstruction is required and the radar simulator, which is the tool able to provide it.

It has been concluded that the use of the simulator does not represent any novel system to solve the problem, compared to the graphic methods of reconstruction by manual plotting on paper. It offers the opportunity to utilize an advanced electronic equipment which in addition to its capability of giving a continuous computarized dead reckoning position of the ships has the advantage of providing a radar picture of the situation as seen from the bridges. This last feature is of special interest in those cases which involve a substantial use of the radar, when the information provided by witnesses can be tested in the simulator.

As has been considered, a number of limitations influencing the solution of the problem have to be taken into account. Those limitations have been divided into two categories, namely those arising from incomplete information about the events which led to the accident and the limitations of the radar simulator itself.

Scarcity and unreliability of information is today a common problem which hampers the investigation process regardless of the reconstruction method selected and pleads for improved data collection systems on board ships, the best solution being automatic data acquisition and recording units. It was recognized, however, that before those recorders become operational, if ever, an exhaustive analysis of the technical and juridical problems involved is required. It is also advisable that this matter be studied by international bodies in order to achieve an optimum solution which satisfies all parties concerned. Most probably, a long period of study can be expected and in the mean time investigators will be obliged to continue the study of casualties basing their analysis on a combination of facts and assumptions, unfortunately many times more on assumptions than on facts.

Should a collision or grounding case be put under test in the radar simulator, insufficient factual information will represent a limitation which has nothing to do with the characteristics of the simulator. Whilst most radar simulators meet the minimum specifications set out in this project, the wide disparity and degree of sophistication of existing simulators requires a preliminary analysis of collision cases in shallow or restricted waters as well as groundings before being put under test in the simulator. Such analysis together with the knowledge of the characteristics of the specific radar simulator which will be used to investigate the case will make it possible to assess the validity of the results and establish whether the complete case or only part of it can be reconstructed using simulation techniques.

The analysis of the two elements involved in this project, that is the investigation process and the radar simulator, does not complete the picture. A fundamental factor which has also to be considered is the person responsible for the reconstruction work using the simulator.

An efficient and effective use of radar simulators either as a teaching tool or for research, requires highly trained operators with a thorough understanding of simulation and the specific simulator they are utilizing. In addition, a good navigational background is a must, as it is necessary to carry out the type of tasks radar simulators have been designed for. Both skills are also fundamental if, as a result of a casualty, a reconstruction work has to be done using the a simulator. Therefore the operator of a radar simulator is the most qualified person to conduct this part of the investigation process. As this task represents a very special field of application of radar simulators, and bearing in mind the different aspects of marine casualty investigation which have been analysed in this work, the operator must also be aware of a number of requirements which are particularly important for the succesful completion of the task. Those special requirements are:

(a) Knowledge of the existing national legislation about marine casualty investigation in the country, as well as a clear understanding of the methods and procedures used to carry out investigations.

(b) Objectiveness and impartiality in the analysis of the different aspects of a case, avoiding any bias in favour of one of the parties to the casualty. An impartial position will strengthen the conclusions reached at the end of the reconstruction work and consequently will be less subject to questioning.

(c) Awareness of the consequences of the findings and conclusions. The reconstruction process is not an academic exercise but an analysis of a real situation which is more than often conflictive. Its clarification is required with specific objectives and the conclusions may not only influence existing rules and regulations but also have consecuences on penal actions against individuals as well as on civil liability matters.

(d) Thorough knowledge of the hydrodynamic behaviour of ships, due to the need to adapt the mathematical models in the simulator to the characteristics of the real ships involved. This is especially the case when insufficient data is available, which must therefore be complemented either with information from similar ships or by the judgement of the operator in order to generate suitable models.

(e) Understanding of human response to different situations. As the situation is today, more than often the balance of information available of a marine accident is more inclined towards unreliable and imprecise data than clear facts. Therefore, when carrying out the reconstruction of a case the operator of the simulator will have to make a number of assumptions which will be based on his judgement of the situation and thereafter an assessment of the possible course of events. His expertise as a navigator certainly plays a major role, but not less important is the consideration of the way in which the people involved in the case might have reacted faced to the real problem and as a result of their own perception of reality.

The reconstruction of collisions at sea and groundings, which led in this project to the analysis of the utilization of radar simulators for that purpose, is a result of the requirement to establish the most probable course of events and the cause or causes of the accident. Insufficient information is a constant in many cases and therefore the desirability of having on board protected data recorders. Should the recorders become mandatory on board and depending on the way in which the information of the recorders will be presented to the investigating body, the need for an additional reconstruction might become irrelevant for the purpose of establishing the circumstances of the accident if the recorder device itself is capable of providing the information. This question has still to be answered, which can only be done after the specifications and operational characteristics of the recorders have been established. In fact, the question forms an integral part with the consideration of the objectives of installing recording devices on board. However, it must be borne in mind that the data recorded may solve a particular case without any need of an extra reconstruction work, whilst the door is still open for two areas in which the radar simulator can play an important role, that is further research and teaching purposes.

In the field of research, the combination of a reliable data bank and simulation techniques can be utilized for a deeper analysis into different aspects of the causes of casualties with the objective of improving safety standards.

In the area of training, as it was considered in chapter 2, the dissemination of investigation reports should include maritime education and training institutes with the objective of carrying out the analysis of marine accident inquiries amongst those who in the future will con the ships. Cases of collisions and groundings at sea replayed in the radar simulator installed in maritime colleges provide an adequate tool to study the real circumstances in which an accident occurred. Whilst trainees can hardly be expected to increase their own experience by learning from the experience of others, at least a certain degree of awareness of the type of situations they might face in their professional life as well as an understanding of the causes which could lead to an accident can be achieved.

* * *

APPENDIX I

MATHEMATICAL MODELS OF SHIP'S RESPONSE

Radar simulators must include in their software models describing the response of the ships to engine and helm orders. Advanced simulators provide for response to environmental influences as well. In this appendix, a brief analysis of the basic physical principles involved and simple mathematical solutions to the problem is made.

The ship's motion responds to the Newton's law of acceleration, which states that the product of the mass and acceleration of a body is equal to the sum of forces acting upon it. Consecuently, a set of differential equations representing longitudinal, lateral and turning motion in a horizontal plane within a coordinate system as shown in figure A.1 can be written. The three equations are as follows:

(1) $(m + mx).u' - (m + my).v.r = X$

(2) $(m + my).v' + (m + mx).u.r = Y$

(3) $(Iz + Jz).r' = N$

where: m = mass of the vessel

mx = added mass along x axis

my = added mass along y axis

Iz= moment of inertia about z axis

Jz= added moment of inertia about z axis

u = speed of the vessel along x axis

u'= acceleration along x axis

v = speed of the vessel along y axis

v'= acceleration along y axis

r = turning rate

r'= turning acceleration

G = centre of gravity

δ = rudder angle

ψ = heading angle

X = sum of forces acting along x axis

Y = sum of forces acting along y axis

N = sum of moments acting about z axis

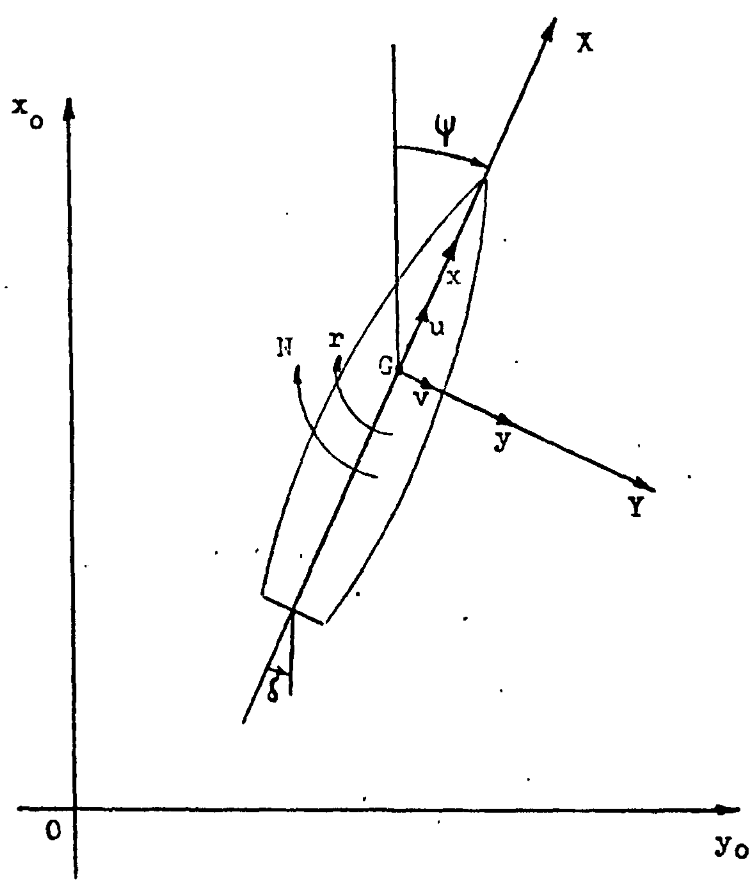


figure A.1

Equation (1) represents the movement of the ship along x axis, equation (2) the movement along axis y and equation (3) the turning motion. The added masses and moment of inertia account for the forces and moment required to accelerate the liquid surrounding the ship.

The values of forces X and Y, and the moment N, are difficult to assess by hydrodynamic theory and a number of different analytic analyses have been made which are not conclusive yet. Another solution to the problem is to carry out experiments with models in towing tanks to predict the values for a given ship form. The solution of the set of equations provides both the longitudinal and transversal movement of the ship as well as the turning behaviour. However, being non-linear differential equations, due to the character of the forces and moments, the solution is normally based on numerical methods.

Ship handling simulators, which require high accuracy of ship's response, make use of the hydrodynamic model. Sophisticated radar simulators are programmed with simplified versions of the differential equations, reproducing in many case the behaviour of selected ships. In a number of less advanced radar simulators, a simple model of ship's response has been adopted, following exponential laws. The resulting expressions provide the speed of the vessel proceeding on a straight line, both while accelerating and decelerating, and the turning rate. The equations have the following form:

(4) $V = (V2-V1).(1-\exp(-t/T1)) + V1$

(5) $V = (V2-V1).\exp(-t/T1) + V1$

(6) $r = K.\delta.(1-\exp(-t/T))$

where: V = speed of the vessel on a straight line

V1= lower speed

V2= higher speed

r = turning rate

δ = rudder angle

K = coefficient

T1,T= time constants

Equation (4) is used when the vessel is accelerating and equation (5) when decelerating. By inspecting these equations, it can be said that the change in speed of the ship as a result of an engine order is assumed to be exponential. On the other hand, it is also assumed that in all cases the ship will proceed straight until reaching the final speed. An analysis of speed curves of real vessels shows that normally they do not follow an exponential law. However, by selecting an adequate value for the time constant T1, a good approximation can be generally obtained. As an example, figure A.2 shows the comparison of the speed decrease of a particular vessel, in this case a coaster of 80 metres in length, with the values obtained by using equation (5). The test is based on three different initial speeds, and at t= 0 the engine was stopped. To obtain the calculated curves, in equation (5) the lower speed V1 must be zero and the value 6.2 minutes was selected for T1. This time constant should be called "equivalent time constant", because it is included in an empirical expression.

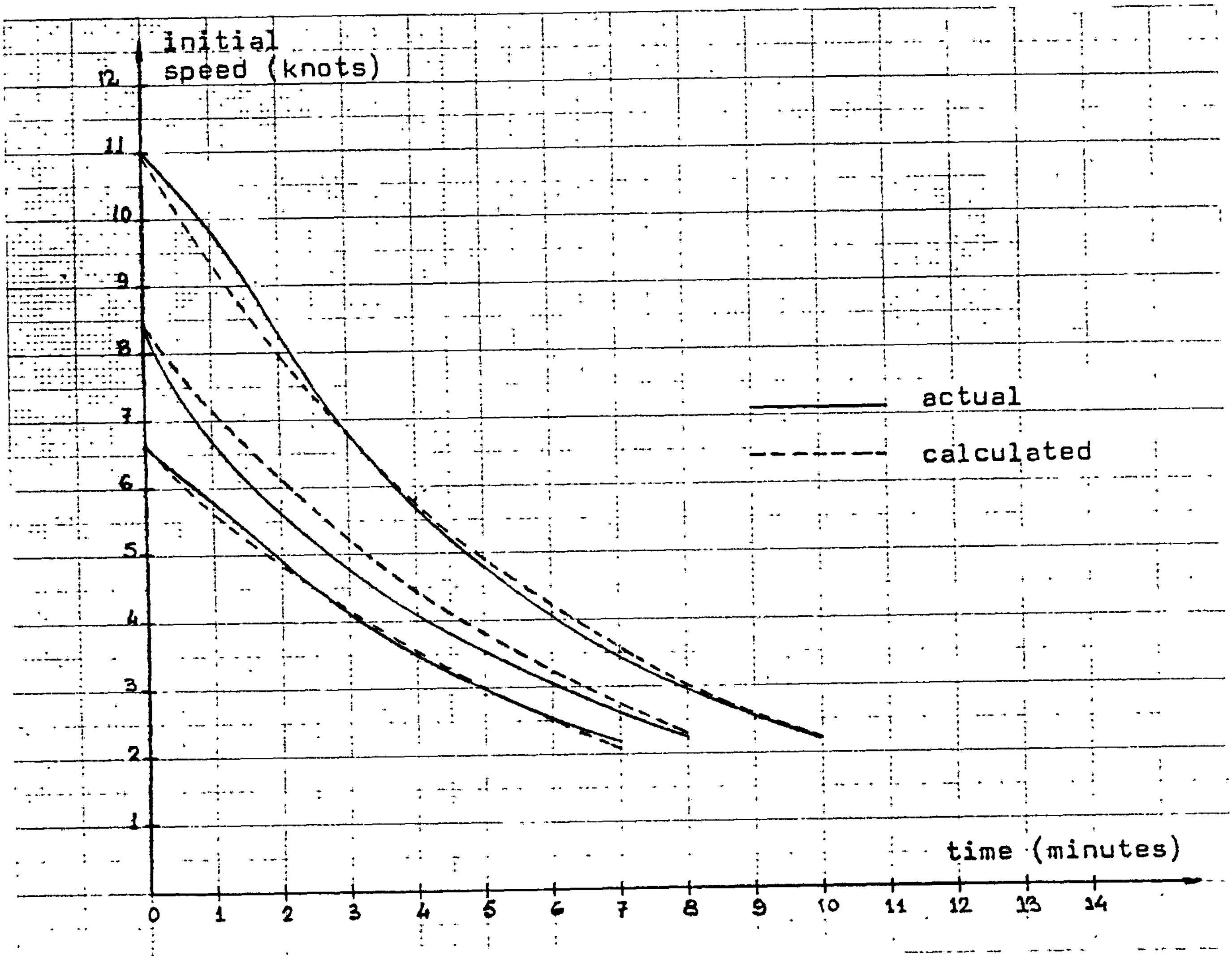


figure A.2

A simple integration of equation (5) results in an expression which gives the distance run by the ship before stopping. If the stopping order is given at t = 0, the resulting equation is as follows:

(7) $S = T1.(V2-V1).(1-\exp(-t/T1)) + V1.t$

where: S = distance run until stopping

In equation (7), t should be the time elapsed until the speed of the ship becomes zero. Also as an example, the calculation of distance run has been made for the same coaster mentioned before, assuming V1 = - 6 knots (theoretical speed full astern) and T1 = 5.6 minutes. In order to obtain the distance run, equation (5) was first used to calculate the time taken to stop the ship for various initial speeds and these times were introduced in equation (7). In figure A.3, the actual curve for the particular vessel is compared with the calculated values.

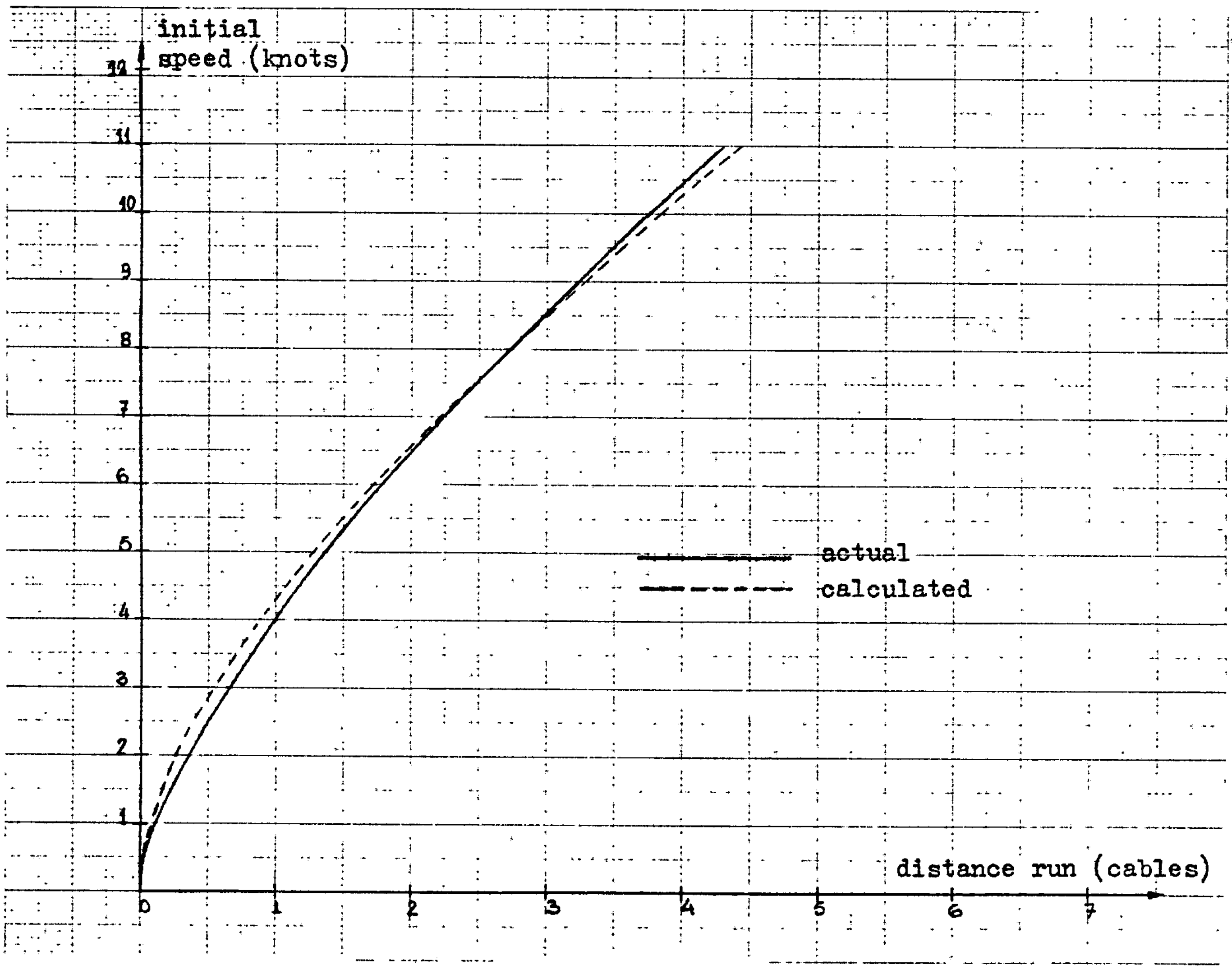


figure A.3

If such type of curves are available for a given ship, the operator of a simulator programmed with this model can choose adequate constants in the equations to obtain the best approximation. This represents a disadvantage in an investigation procedure, because of the need of real data of a kind, which is seldom available when analysing a collision case. The second assumption, which is that the ship proceeds on a straight line, is not always valid. This is specially the case when the vessel reverses her engines and in those cases, therefore, an additional error will be introduced when using this type of mathematical models.

Equation (6), which provides the rate of turn, is the expression known as K-T equation and is the simplest mathematical model of ship steering, based on the Newton laws. K and T are the steering quality indices which can be assessed for a given ship by making steering tests. The equation shows that the turning rate increases exponentialy at the beguining and afterwards this increase slows down until reaching the constant value:

$$r = K.\delta$$

The simple exponential model does not provide for the reduction of speed which occurs during a turn and therefore it is normally included in the software as a programmable reduction expressed in percentage of the speed before starting the turn.

LIST OF ABBREVIATIONS

ARPA	Automatic radar plotting aids
CGI	Computer generated imagery
CPA	Minimum distance at closest point of approach
CRISTAL	Contract Regarding Interim Supplement to Tanker Liability for Oil Pollution
FUND	International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage
GRT	Gross registered tonnage
ILO	International Labour Organization
IMO	International Maritime Organization
MSC	IMO Maritime Safety Committee
SOLAS	International Convention on Safety of Life at Sea
TCPA	Time to closest point of approach
TDW	Deadweight tonnage
TOVALOP	Tanker Owners Voluntary Agreement Concerning Liability for Oil Pollution Damage
VHF	Very high frecuency transceiver
VTS	Vessel traffic system

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