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DESIGN AND DEVELOPMENT OF AN ELEVATING STRETCHER TROLLEY

by

Sara L. Cox B.A.(Hons) Industrial Design

being a thesis submitted in partial fulfilment of

the requirements for the CNAA degree of

MASTER OF PHILOSOPHY

This project was sponsored by

The Science and Engineering Research Council
in collaboration with F.W. Equipment Co., Ltd.

Department of Mechanical &
Production Engineering
Sheffield City Polytechnic

January 1985

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ABSTRACT

The thesis describes the information search and development of a new design for an elevating stretcher trolley.

The project was sponsored by F.W. Equipment Co., Ltd. of Bradford who required a new design for their existing stretcher trolley that has been on the market for the last ten years.

The information search period consisted of the identification of a suitable method of information collection. This involved visits to ambulance stations to question ambulance crews and observe the trolley during use, where possible. The information gathered during these visits was analysed with emphasis on the ergonomic priorities and used to produce a performance specification against which both the existing and the new design could be evaluated.

The design development comprised identification of design priorities that enabled the complex structure to be separated into related components within the whole context of the design. This was followed by the generation of ideas for solution to the problems identified, development of viable solutions to mock-up level and the development of a first prototype. The second prototype was developed from the first incorporating the improvements and design changes arising from the evaluation of this. A handling evaluation of the second prototype and suggestions for a production model conclude the project.

January 1985

ACKNOWLEDGEMENTS

The author wishes to thank the following for their assistance during this research project.

Mr. G. Cockerham B.Eng, M.Phil, C.Eng, M.I.Mech.E for his overall guidance and sympathetic supervision and particular help with mechanical problems.

Mr. G. Wilson Dip.AD, M.Des. RCA for his assistance with the design.

Mr. J. Mitchell M.Sc, B.A, MSCP for his assistance with the ergonomics and information search methods.

Mr. T. Coward M.DEs. RCA, MSIAD.

Mr. L. Harris of F.W. Equipment Co., Ltd. for instigating the project and supporting it during its progress.

Mr. J. Evans, Works Manager, F.W. Equipment Co., Ltd., for his assistance in obtaining information on production methods and materials and building Prototype 2.

Dr. R. Snook MD, Royal United Hospital, Bath for his help and advice in providing information.

Mr. C. Hayne, District Physiotharapist, Derby Royal Infirmary for his assistance in arranging visits.

All ambulance crews particularly those at Ambulance Station A who allowed me to travel with them during their work.

Station Officers.

Training Officers, particularly Mr. Cave of South Yorkshire Metropolitan Ambulance Service.

Gratitude is also expressed to Jeff of Bradford for making many of the parts for Prototype 2 and Mr. R. Sidebottom, technician, Sheffield City Polytechnic for completing the Prototype ready for the handling evaluation.

Finally gratitude must be expressed to Mrs. V. Cox for typing the thesis.

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1 INTRODUCTION

1.1 Development of the Ambulance Service

1.1.1 A stretcher is defined in the Oxford Illustrated Dictionary (1) as 'an oblong frame with handles at each end for carrying sick or wounded persons on'. Though this remains the basic form, there are many types of stretcher available today, some designed for specific rescue operations, others for general use but varying in their complexity from the simple pole and canvas stretcher to the more versatile but complex wheeled versions. However, the sole purpose of a stretcher remains that of enabling patients to be transferred from one place to another with less discomfort and risk of further injury to the patient and better handling facilities for the bearers than would be possible with direct handling procedures.

1.1.2 The problem of moving sick or injured persons has exercised man's ingenuity for centuries and the earliest form of transport, recorded in ancient Egypt and Persia, for those unable or unwilling to walk or ride is the litter. This is described in the Encyclopaedia Britannica (2) as "a portable bed or couch, open or closed, mounted on two poles and carried at each end on man's shoulders or by animals" and survived as the main transport for sick or injured persons until the introduction of the wheeled version in London and Glasgow in the late 1800's. This description of a litter bears many resemblances to the definition of the stretcher given above. A good historical account of activities around this time is given by McDonald, Bank & Ledingham (3). They found that for centuries, transport of the sick was an individual affair depending on the person's circumstances and friends and it was not until the 1600's when epidemics in London highlighted the need to organise transport for those afflicted that the 'pest coaches' noted by Samuel Pepys in his diary of 1665 became the first recorded organised transport for sick persons. They also described how in the eighteenth century war became the dominating influence on the development of casualty transport with the need to move large numbers of injured from the battlefield to hospitals or field stations. Under the influence of army surgeons, transport was organised after the Battle of Blenheim using any form of wheeled vehicle available from the surrounding countryside for this purpose.

1.1.3 From this rough and ready situation the French produced the first properly organised transport vehicles in 1762 and these were called 'hôpital ambilants' or mobile hospitals. Further developments in casualty handling were attributed by McDonald, Bank & Ledingham at (3) to a French Army surgeon. He trained the first corps of field litter bearers, and this was followed in 1792, when Baron Larry, the surgeon major to the hospitals of the Rhine, developed a lightweight ambulance transport that provided facilities for treating injuries on the field as well as a means of evacuating casualties to the rear of the battlefield.

1.1.4 The next major step in the development of an ambulance service came in 1864, and was attributed by Dr. Snook (4) again as a result of war, when at the Geneva Convention, wounded soldiers, ambulance staff and equipment were given the protection of neutrality. This marked the start of the Red Cross.

1.1.5 He saw the Franco-Prussian war as a further stage in developments with the introduction of a horse drawn ambulance around 1870. This vehicle was equipped with two permanent stretchers and could also carry seven lightly wounded. It was found, however, that these ambulances were "very difficult to turn sharply, the roofs being made only of canvas did not wear well and the permanent stretchers were found to be difficult in use" (4). Improvements were suggested that these stretchers should have larger handles and not be permanently fixed, avoiding the problem of moving the wounded from field stretcher to the ambulance stretcher, enabling the stretcher used in the field to be put straight into the ambulance. Unfortunately today, the problem of the transfer of patients from one situation to another or from field equipment to ambulance equipment then hospital gear is still with us.

1.1.6 By the first World War McDonald, Bank & Ledingham at (3) found that motorised ambulances were coming into use and the ambulance vehicle from then on developed as technological advances were made in the motor vehicle industry. However, these advances in the transport of the wounded were not reflected in civilian life until the end of the First World War. In the late 1800's hand litters were still in use by the police who attended all street accidents and illnesses, and wheeled litters came into use in London in 1880 and Glasgow in 1882. An attempt was made to form a civilian ambulance service at this time, but though the St. Andrews Association in Glasgow was fairly successful, the London Home Ambulance Service was not, probably because calling an ambulance cost more than hiring a cab!

1.1.7 From this period until the formation of the N.H.S. it was noted by Dr. Snook (4) that organised ambulance services were usually run by voluntary bodies such as the St. John's Ambulance Service, Red Cross and in Scotland the St. Andrew's Association. These ambulances carried only the most basic equipment of a single stretcher or stretchers, blankets, dressings and splints.

1.1.8 In 1948, Section 27(1) of the N.H.S. Act 1946 (5) imposed a duty on local authorities to provide free ambulance transport. Lea (6) found that this was implemented by the authorities who either provided the service themselves or continued to use that already provided by voluntary bodies such as the Red Cross or St. John's Ambulance Service who they appointed as agents. It was not long after this that hospitals began to use the ambulance for general patient transport and not solely for emergency cases and to make increasing demands on them for out patients work. This demand has now grown to the extent that in 1974 stretcher use only formed 9% of the cases carried.

1.2 Development of the Stretcher Trolley

1.2.1 In the years between 1948 and 1967 each county had its own individual ambulance service resulting in a large variety of equipment in use and no compatibility between services. Then in 1965 Woodham (7) notes that a working party under the chairmanship of Dr. E.L.M. Millar was set up by the Ministry of Health to advise on the equipment and training of staff in the ambulance services provided under the National Health Service Act (5), and to give recommendations, after consideration of developments in the field of accident surgery, on the training of personnel. On examination of the equipment, the working party led by Dr. Millar (8) found that there were fifty different types of stretchers in use and sixty-two variations on the number and types to be carried in an ambulance. They noted that this variety created difficulties in the transfer of patients between ambulances and delays at the hospital where their gear was not interchangeable with hospital equipment. They also found many requests for more standardisation of stretchers.

1.2.2 In their examination of the different types of gear in use the working party divided them under three main headings:-

a) Gear for outside loading:- this enabled a loaded stretcher to be put into or taken out of an ambulance by using a cradle on which the stretcher was placed, then the whole unit swung into the ambulance. Normally mounted on the near side of the vehicle these units could not be used unless the patient was put onto the stretcher outside the ambulance. This type of gear usually had its own patent stretcher making it unsuitable for use with other equipment and the ambulance fitted with one of these also had a fixed stretcher mounting on the opposite side thus making use of two types of equipment in one unit.

b) Gear for inside loading:- this consisted of a bench inside the ambulance onto which a canvas pole stretcher could be fitted. There were usually two in a vehicle and they could be padded increasing the comfort for a stretcher patient and making them suitable for carrying sitting patients. This enabled both sides of the ambulance to be untilised, however, it was necessary when loading to carry the patient into the ambulance on a carry chair or stretcher, then transfer to the bench.

c) Ambulance Trolleys:- various types were found, some with padded tops that serve as stretcher supports, beds or seats. These enabled the patient to be carried into the ambulance on a carry chair or stretcher then transferred as above and they provided the additional facility that the trolley could be taken to the patient who was placed directly on it and returned to the ambulance for loading and securing (8).

1.2.3 The working party went on to examine, by demonstration and discussion with ambulance officers, the three types of equipment above and found that with "Gear for outside loading" the disadvantages outweighed the advantages considerably, whereas with "Gear for inside loading" and "Ambulance Trolleys" the situation was reversed. In consideration of these two types of equipment they found that Ambulance Trolleys offered greater facilities for both patient comfort and handling and their recommendations for their use were as follows:-

"With proper design, disadvantages (1) and (2) above attendant on ambulance trolleys could be eliminated; if used with pole and canvas stretchers which we recommend trolleys could then provide most of the advantages, with few of the disadvantages, of other types of stretcher gear - and additional advantages which are completely beyond the scope of these other types. They should therefore be developed as standard equipment for all ambulances."

Note:

(1) refers to the danger of unattended trolleys running away downhill unless safety devices are incorporated.

(2) refers to the means of locking the trolley into the ambulance body.

1.2.4 This report was implemented through the Ambulance Service Advisory Committee (ASAC). It was superseded in 1974,during the reprganisation of the National Health Service, by the N.H.S. Supply Branch advised by the Ambulance Service Purchasing Advisory Group (7). This is the background to the Ambulance Service today, and the recommendations that the Millar report and the Ambulance Advisory Committee (9) made then, form the criteria summarised below, against which all trolleys presently in use or considered for use by the Ambulance Service are evaluated.

1.2.5 The A.S.A.C. recommendations (Appendix A) give a broad specification against which ambulance stretcher trolleys can be evaluated. It is, however, based on a fixed height trolley and not on the elevating model. It covers the general requirements of use with other equipment and in the ambulance, the materials and overall dimensions of the frame, and the structure in relation to use to avoid damage both in and out of the ambulance. It goes on to cover specific features such as the adjustment of the backrest and the drainage position and the shape of the mattress. Patient safety on the trolley is covered by the recommendation of the use of guard rails and safety belts, and safety of the trolley in the ambulance by the suggestion of locking devices to fit in the ambulance body. It also suggests the use of foot brakes on the wheels of the trolley. This specification is very general referring to the features needed to obtain the required performance in a stretcher trolley making it suitable for ambulance use within the National Health Service.

1.3 <u>The Stretcher Trolley</u>

1.3.1 During the ten years that the stretcher or ambulance trolley has been in use, equipment in the Ambulance Service has become more standardised allowing some interchange with hospital equipment (the stretcher carries a green sheet that can be transferred to a hospital trolley and replaced by one from the hospital trolley). It also allows the supposition of full interchangeability of trolleys between ambulances in case of major disaster. This interchangeability has become a major consideration in the design of trolleys today in response to the need to provide for the possibility of a large scale disaster, such as a major rail or air crash, where fleets of ambulances from different areas would be mobilized. In this situation a non-standard trolley would cause delay in the evacuation of the injured if it could only be used in a particular ambulance, whereas a standard trolley

Fig. 1

The roll-in, roll-out trolley being loaded into an adapted ambulance. Note the steep angle of the trolley while loading.

would be acceptable by all.

1.3.2 Another factor that influenced the choice of stretcher trolley for ambulances was the increasing use of the ambulance to transport patients to and from outpatient departments. The trolley allowed the ambulance to be utilised as a dual purpose vehicle by providing a padded bench type seat to accommodate 3 or 4 seated persons or a bed for one person. However, this dual purpose has led to many problems because such an arrangement must depend on compromise resulting in inadequate space for attending to an emergency case - it is very difficult to administer mouth to mouth rescusitation and cardiac massage with both attendants working on the same side of the trolley - and an unsuitable arrangement of seating for sitting cases, many of whom feel ill when travelling in a sideways facing position. Rockell (10) states that the present trolley and seating arrangements make nursing during the journey difficult as the attendant has to sit on the opposite trolley or else on a stool-like seat attached to the patient's trolley. Neither of these provides adequate support or restraint during a journey that may be taken at high speeds. He further states that the use of trolley stretchers has led to an increase in back injuries due to the increased weight and the greater difficulty that crews experience in loading and un-loading the laden stretcher trolley. Snook (11) notes that in a survey of 28 ambulance men, nine had to be off work with backache for periods of one to sixteen weeks totalling 52 weeks in the past five years, however, he attributes this not to the use of trolleys but to the design of the ambulance and the height of the loading platform. Undoubtedly, unless the roll-in/roll-out trolley as shown in Fig.1 is used, this will remain a problem until the ambulance is redesigned to accommodate easier loading facilities. Roll-in/roll-out trolleys have been tried but proved unsuitable for the type of ambulance with internal wheel arch, that are used in Britain. As Fig.1 shows, the trolley needs to be rolled up onto a ramp over the wheel arch leaving it on a slope and unsuitable for sitting cases because of this and its low height. This type of trolley also requires careful handling as it is easily folded accidentally as observed by assistant nurse and ambulance driver (12) and is normally of fixed height because of the very complicated mechanism required to provide both variable height and folding legs.

1.3.3 There is little information available on the actual usage of the trolley though research by Dr. R. Snook (11) has been undertaken on the effect of the ambulance ride on a patient, and on the use of a 'floating stretcher' to improve ride in view of the unlikely event of the development of a purpose built ambulance. Snook & Pacifico (13) found that this unit, consisting of an electrically operated sprung base mounted in the ambulance and on which the trolley is placed, greatly improved the ambulance ride but, unfortunately, the cost is considered prohibitive and it has the disadvantage in the present system of allowing only one stretcher trolley to be carried at a time and, since it cannot be easily dismantled, of preventing the ambulance from carrying out normal services. These units are in use, but only in limited quantities in specialist services. A cheaper version has been recently developed at Bath University (14) but it is not known yet how effective this is and whether it can be adapted to the present dual purpose role of the ambulance.

1.3.4 There is little doubt that transporting a patient can cause varying degrees of discomfort and in some cases be actually dangerous (10) & (11), and though this is mainly due to the effects of the ambulance design, improvements in the trolley design could give some relief to the problem. For instance, it should be possible to assist in the maintenance of an airway, found by McDonald, Bank & Ledingham at (3) to be the cause of many problems in casualty transportation, though the trolley design is severly restricted by the ambulance design and by its dual purpose use. However, Woolham (6) found that the use of trolleys, especially when elevated to hospital trolley or bed height, made them easier to wheel and gave a reassuring feeling to the patient and Rockell (10) states that:-

> "Undoubtedly trolley stretchers, with their ease of adjustment and padded mattress, have made some contribution to patient comfort, but there is ample scope for further development of stretchers to provide greater patient comfort and ease of handling."

1.3.5 The above statement summarizes the present stage of stretcher trolley design but though much has been said about the faults of the existing design there has been no indication of ways in which these can be improved. It is intended to rectify this and produce an improved design during this project, the aims of which are set out below.

1.4 Aims of the Project

1.4.1 Initial contact was made with F.W. Equipment Co., Ltd., in 1982 when the researcher was involved in the design and prototyping of a rescue stretcher, primarily for mountain rescue, as part of the final year work for a B.A. (Hons) Degree in Industrial Design at the Sheffield City Polytechnic. On completion of this project the company was approached with the suggestion for further development of the rescue stretcher, but this was rejected on the grounds of cost and the limited market. However, the company proposed that the following research into one of their products, the'Super 4' elevating stretcher trolley, should be undertaken and a Collaborative Training Award was obtained from the Science & Engineering Research Council to fund this.

1.4.2 The present family of stretcher trolleys supplied by F.W. Equipment has now been in use for ten years and it was felt by the manufacturers that it was time to examine the role of the trolley and its usage in the ambulance today taking into account past experience on its handling, maintenance and general use, and possible future developments in accident emergency that may make additional demands on the trolley.

1.4.3 The project aims, therefore, firstly to examine present methods of casualty transport and the role of the trolley in this particular context and to discover the handling processes involved and any problems relating to these that have emerged over the last 10 years. It is also necessary to examine trends in emergency care and to discover what, if any, changes are likely to occur within the life of the trolley design and from this data to establish certain criteria against which the present trolley can be evaluated and which will form the basis for future designs. In order to achieve this the following areas of information search were proposed:-

1) Present methods of emergency treatment, patient handling and care.

2) Future developments in emergency treatment and subsequent changes, if any, in patient handling.

3) Present influences and future developments within the emergency services that could affect the use of the stretcher trolley.

4) Specific customer requirements

5) The market requirements.

6) Materials and the production methods available.

Secondly the project aims to use the data collected from the information search outlined above to produce a performance specification against which a new design would be developed. It is intended that this would occur in the following stages:-

1) Data analysis and development of a performance specification.

2) Development of preliminary designs.

3) Construction and evaluation of prototype 1 to test design principles.

4) Detailed design development.

5) Construction and evaluation of prototype 2.

The overall project plan is shown in Fig.2 in which a period of time is allocated to each identified phase. This is intended as a guide to the project development.

1.4.4 Of the areas of information search proposed the first four form the major part of this phase of the project. Some information on items 5 and 6 was available from the company who hold 95% of the trolley market in England and Wales. It is a relatively small but specialist market with trolleys sales estimated at approximately 1000/year. These will mainly be fitted into new ambulances using two per ambulance. The company is not equipped for the manufacture of trolleys though it is for soft goods and at present trolleys are manufactured in the United States and imported for final assembly here under a trade agreement. The decision to evaluate and revise the design of the present trolley was partly influenced by this as it was felt that existing designs developed for the American market did not entirely suit the English market and partly for economic reasons, with the devaluation of the pound against the dollar and the consequent rise in price of the imported trolleys. The factory, then, is set up for basic assembly with some facilities for tube bending, jig drilling and small lathe work. The new trolley design must, therefore, accommodate not only the ergonomic and mechanical features required but be also suited to this type of manufacture.

1.4.5 It is intended that the second prototype should be suitable for handling and manufacturing evaluation. This would enable a final design proposal to be made accommodating any changes that appear necessary as a result of the evaluation of the handling exercise.

2 METHOD OF WORKING AND DATA COLLECTION

2.1 Introduction

2.1.1 On starting this project it was necessary to identify areas about which information was required then to decide the best way of achieving this. It was decided that the approach to the information search should meet the following criteria:-

1) It should enable a representative portion of the defined population (ambulance officers) to be involved.

2) It should enable a variety of information to be obtained.

3) It must be carried out within a defined limited timescale.

M.J. Wilson of the Open University (15) defines three approaches to acquiring information and by examining each against the criteria it was possible to eliminate those unsuitable to this search. These were rejected for the following reasons:-

1) Ethnographic approach - this relates to the study of people and life style and is very time consuming. As it deals primarily with small groups it is not representational of a population.

2) Experimental approach - this is largely scientific and relys on the measurement of variable data against a control. It is, however, not possible to fix all the variables when examining groups of people and is used only to find specific information.

This left the third or survey approach which proved suitable as it enables a representative population to be used and more than one facet of that group to be examined at any one time. It is also suitable for use where information is required within a short time span. It was recognised, however, that it would be limited in that the information obtained is dependant on personal reaction to the format used and there is no way of checking the genuineness of each statement.

2.1.2 Once the survey approach had been established it became possible to examine further the methods of collecting data. Betty Swift of the Open University (16) defines two ways of collecting data. These are:-

1) Questioning - this includes both written questionaires and oral ones (interviews).

2) Observation - where an object or process is observed and reported on.

The questioning process can be further divided into

a) Structured questions - where set questions are answered with either yes or no and there is no room for variations of attitude. These are good for comparison trials.

b) Semi-structured questions - where there are some set questions but allowance for the interviewee to add relevant comments of his own.

c) Unstructured questions - where the subject can talk randomly about the research topic.

It is possible to use a combination of these methods of data collection and it was decided that the most suitable method for this project would consist of semi-structured interviews together with participant observation. Written questionaires were eliminated because of the short time allowed for data collection and because it was felt that a combination of interview and observation would provide more relevant information than a formal interview or questionaire. The use of this method was also dictated by the nature of the work in which the subjects to be interviewed were involved. It was also possible by using this approach to run a pilot study in which the written or oral form of the questionaire was tested, allowing it to be adjusted to obtain the maximum relevant information before undertaking the main interviewing sessions.

2.1.3 The above method enables the information gathering stage to be completed. This information is then analysed and used to formulate the performance specification at which stage the design process begins with the generation of ideas to solve the problems identified.

2.1.4 Techniques used

The research areas to be studied and developed have been discussed in paragraph 1.4.3. The techniques described here relate to the information gathering processes used to obtain both background information to allow the trolley to be seen in context and direct information relating to its usage. However, the whole project was carried out in the following stages:-

1) Literature search
2) Establishment of the research approach and development of the methods to be used
3) Data collection - General and specific
4) Analysis
5) Problem identification
6) Developemnt of a performance specification
7) Existing trolley evaluation
8) Preliminary design
9) Development of Prototype 1
10) Detail final design
11) Development of Prototype 2
12) Evaluation of Prototype 2
13) Final design proposal

A diagram showing the relationship of these stages

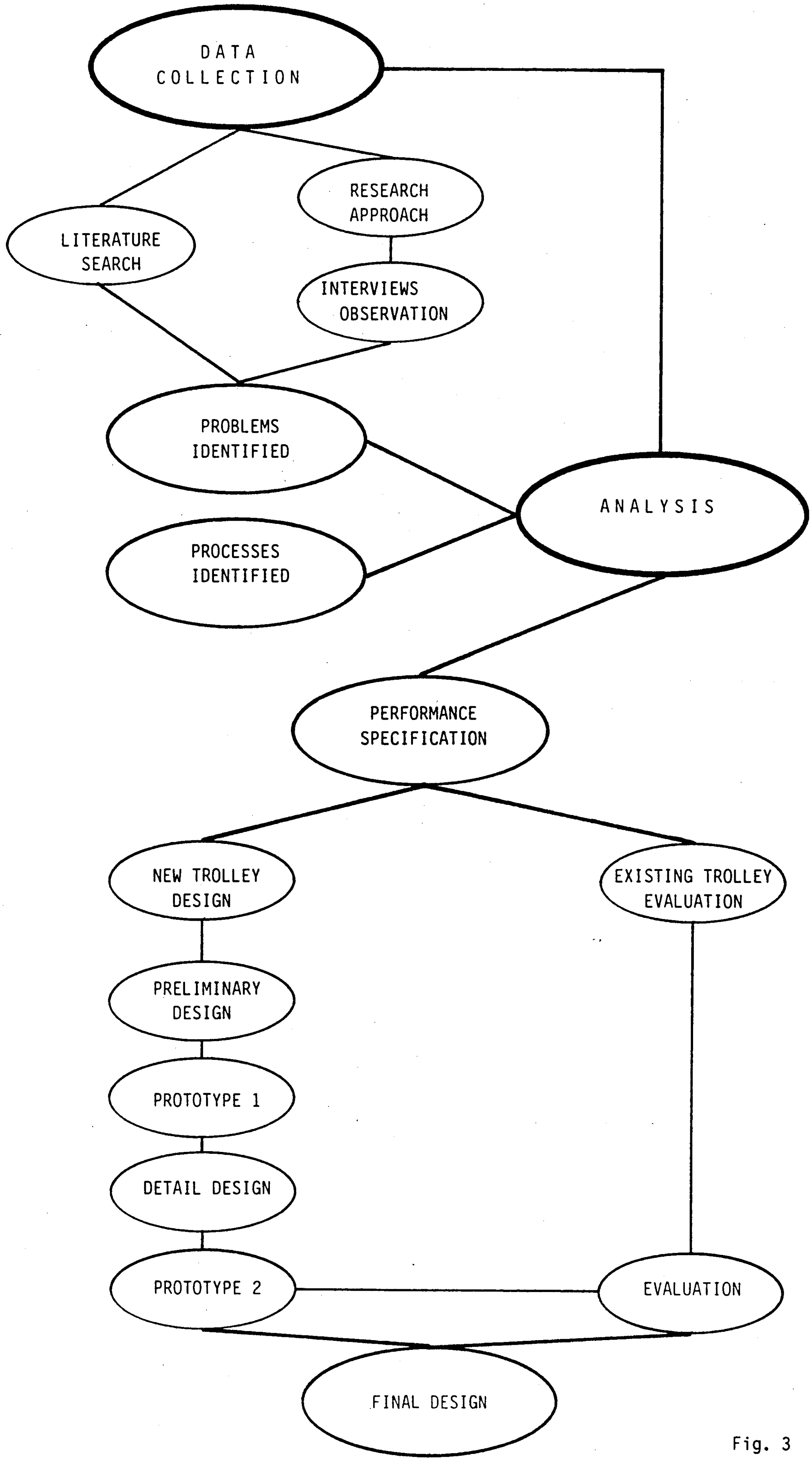

DATA COLLECTION
LITERATURE SEARCH
RESEARCH APPROACH
INTERVIEWS OBSERVATION
PROBLEMS IDENTIFIED
PROCESSES IDENTIFIED
ANALYSIS
PERFORMANCE SPECIFICATION
NEW TROLLEY DESIGN
EXISTING TROLLEY EVALUATION
PRELIMINARY DESIGN
PROTOTYPE 1
DETAIL DESIGN
PROTOTYPE 2
EVALUATION
FINAL DESIGN

Fig. 3

to each other is shown in Fig.3, however it is proposed in this chapter to discuss only the methods used and problems encountered in the first 3 stages. The data collected in stages 3, 4, 5 & 6 will be discussed in chapter 3 and the Design Processes in their relevant chapters.

2.2 1. Literature search

2.2.1 This revealed little information of direct relevance to the handling of the trolley but there were several articles relating to the trolley in the context of the total emergency care process. Medical journals were found to be the most useful source of information on emergency care and ambulances but in order to identify the relevant articles it was necessary to determine the key words under which these would be listed in the journal abstracts, as a search under 'trolleys' produced only information on instrument or laundry trolleys. These proved to be 'transport' and 'patient handling'. The articles identified proved in most cases to contain references to ambulance trolleys only in one or two paragraphs, but there were several interesting works on ambulance rides by Snook & Pacifico (13), ambulance interiors and equipment by Woodham (7) and Rockell (10) as well as information on the effects of transport on a patient by McDonald,Bank & Ledingham (3) and Snook & Pacifico (13). It was also possible to obtain information on the history of the ambulance service and the trolley from the Oxford Illustrated Dictionary(1),Encyclopaedia Britannica (2) and articles by McDonald, Bank & Ledingham (3) and Snook & Lea (6). The most relevant information relating to trolleys themselves, however, is the Working Party Report on Ambulance Training & Equipment (8) which, in 1967, set out briefly the advantages and disadvantages of using trolleys. Articles on hospital trolleys by Weston & Goodhead (17) and Murray (18) were found usefual as some of the conditions and requirements are the same as for ambulance trolleys. However, despite the shortage of relevant information the literature search provided a useful background and insight into the ambulance service and emergency care process.

2.3 2. Establishment of the Research Approach & development of method.

2.3.1 The lack of information available through the literature search and the nature of the problems indicated the use of the survey approach with opportunity sampling of ambulance crews as available at stations in five regions, chosen for their accessibility, differing population densities, industrial, urban or rural bias and crew training levels. Training schools in two regions were also visited where training officers were interviewed. These stations were recommended as being representative of their particular region.

2.3.2 The methods chosen to obtain the required data involved:-

a) Semi-structured interviews with ambulance crews, station officers, training officers, accident and emergency staff, maintenance and cleaning staff.

b) Participant observation.

Patients have been omitted from the above list because it was felt that though they are largely involved in the use of the trolley it would not be possible to interview them in transit as this would increase the distress in an already stressful situation nor would it be possible, on the grounds of privacy, to obtain follow up information. Research into patient reaction was, therefore limited to observation and reports through ambulancemen.

Table 1

In the following table the places visited are listed in chronological order giving the research methods used and types of information collected.

VISIT	METHOD	INTERVIEWEES	INFORMATION COLLECTED General	Specific
1) Training Centre/ Ambulance Station A	Interviews	Training Officer, Station Officer, Crews available	x	x
	Observation			x
2) Ambulance STation B	Interviews	Crews (specifically) others generally	x	x
	Observation	3 - '999' duties	x	x
	Personal experience			x
3) Royal Hallamshire Hospital, A & E Department	Interviews	Casualty Officer	x	x (hospital trolleys)
4) Ambulance Station A	Interviews	Station Officers, crews, (1 crew specifically)	x	x
	Observation Personal experience	Handling Demonstration	x	x
5) Ambulance Station A	Interviews	Crews - 2 shifts of 4 men each		x
	Observation	8 - '999' duties	x	x
6) British Red Cross	Interviews	Ambulance Personnel	x	x
	Observation Personal experience	Ambulance layout		x
7) Regional Training Centre	Interviews	Training Officers	x	x
	Observation			x
8) Ambulance Station A	Interviews	Crews - 1 shift of 4 men		x
	Observation Personal experience	6 - '999' duties		x
9) Ambulance Station A	Interviews	Crews		x
	Observation Personal experience	7 - '999' duties		x

VISIT	METHOD	INTERVIEWEES	INFORMATION COLLECTED General	Specific
10) Redfearns National Glass Barnsley	Interviews	Industrial Nurse Ambulanceman	x	
	Observation		x (relating to a special trolley)	
11) Ambulance Station A	Interviews	Crews		x
	Observation Personal experience	3 - '999' duties		x
12) Ambulance Station C	Interviews	Crews, Training Officer	x	x
	Observation	2 - '999' duties	x	x
13) Ambulance Station D	Interviews	Crews, Training Officer	x	x
	Observation			x
14) Training Centre & Ambulance Station	Interviews	Training Officers, Crews on training, Crews on duty	x	x
	Observation			x
15) Training Centre E	Interviews			x
16) Ambulance Station A	Interviews	Station Officer, crews, 1 shift of 4 men		x
	Observation	3 - '999' duties		x

2.3.3 Most visits involved one day lasting between 4 - 8 hours, but it is possible to repeat visits to one particular station to verify information and obtain further specific data. Visits usually comprised the collection of two sets of data:-

1) General - consisting of information relating to the processes used during handling operations.

2) Specific - relating to information about indidvidual components or specific problems.

Initially visits concentrated on general information, especially the first two which were used as a pilot study to test the question format and content. Subsequently, it was possible to concentrate more on specific data though general information was always collected at the start of visits to new areas. Table 1 shows a list of visits made, the methods used to collect information and the persons interviewed. It shows information collected under the two headings General and Specific as expressed above.

2.3.4 During some visits, it was possible to observe the patient handling process during '999' duties and further subjective data was obtained from a patient and trolley handling demonstration session. Again the first two duties were used as the pilot study to gather general information on the whole process, and subsequent duties to observe specific problem areas and details of the handling process. During these observation periods subjective tests were carried out involving the handling of the trolley in all its positions while unladen, and acting as casualty for the handling demonstration. It also involved assisting with the handling of the trolley while in use on emergency duties. This gave a valuable insight into the problems encountered and allowed the researcher to observe actions and positions that through habit would remain un-remarked by the crews.

2.3.5 This method of information collection was chosen as being the most suitable for the situations involved, making the most effective use of the time available at each station and the limited time of the crews while on duty. The semi-structured interviews proved to be loose enough to promote discussion and the raising of other points relevant to the trolley. The observational method was chosen as a means of obtaining certain information that the crews and their patients were, perhaps, unaware of, and as a way of becoming familiar with the whole patient handling procedure.

2.4 3. <u>Data collection</u>

2.4.1 In all, sixteen visits were made to ambulance stations, training schools and Accident & Emergency (A & E) departments as show in Table 1. It was found necessary to use the first three visits as a pilot study in which the initial questionaire was tested leading to discussion and to further relevant questions. The revised questionaire given below was then used as the basis for all later visits and these normally took the following form:-

a) Introduction of the interviewer and the project by an ambulance officer.

b) Checking the handling process and trolley usage as compared with information already obtained.

c) Obtaining specific information relating to known difficulties.

d) Identification and discussion of points arising from these and on further difficulties or suggested improvements.

2.4.2 Information Required

1) Stretcher Usage
   - Are exceptional weights frequently encountered?
   - Are there any problems handling the trolley due to its weight ie. fears of bending, breaking etc?
   - Do female attendants have any particular problems with control handles, size, reach etc?
   - Any problems with materials due to chemical contact or in cleaning?

2) Elevating mechanism
   - Is this used? If so:-
   - How? - ie side or end loading and what problems?
   - Where? - in hospitals - at accident sites etc?
   - Why? - for ease of use, hospital transfers or other? When transferring do they slide across or lift only? Is there any feedback from casualty?

3) 'Fowler' position
   - Is this used? If so:-
     Any problems? - Is it used with the trolley in or out of ambulance?
     Does it need any adjustment?

4) 'Trendelenberg'
   - Is this used? If so:-
     Any problems?
     How is the patient loaded on the trolley, into the ambulance with this position?
     When is it used?
     What happens when off-loading?
     Is it used during the journey?

5)	Sitting patients	- Any complaints about seat height, width or security?
6)	Security	- Any problem with security of a reclining patient?
7)	Field carry	- Any particular problem?
8)	Wheel lock	- Where are they used? Any difficulties?
9)	Inter-hospital transport	- Any problems? ie. intra-venous drip stand, oxygen/entonox bottle - patients' gear.
10)	Hyper-extension/cardiac arrest feature.	- Is it used? If so:- How easy is it to use? Are there any problems?
11)	Other problems. ie. handles -	
	towing	- Any difficulties?
	carrying	- Where would be the most comfortable carrying position?
	slides	- Any difficulties?
12)	Mattress	- Any problems with use? " " " cleaning? " " " static electricity?
13)	Casualty handling	- Any particular problem? Are straps used - if so why and where?
14)	Other stretchers	- What other types may be used and are they used on top of or as well as the trolley?
15)	Other equipment	- ie. oxygen/entonox - what relationship with the trolley?
16)	Check ambulance type and layout.	

For hospital:

1) Are casualties attended to on the trolley in the A & E department?

2) Are they transferred to another department before treatment or special treatment before transfer to the hospital trolley?

3) Would it be used or should it be used with the equipment before casualty transfer, ie. x-ray equipment?

4) Who else is likely to use it, ie. nurses?

5) Use of infusion - is this likely to become more frequent?

Specific detail:

1)	Hyper-extension position	- Does it need the upward slant then head back? - can it be flat?
2)	Fowler position	- Its use? - any recommended heights?
3)	'Trendelenberg'	- Use? - what about anti-trendelenberg?
4)	Flexible bed system	-
5)	Casualty transfer	- Lifting only or sliding across? Use of roller as in "The handling of patients" or guide for nurse managers?
6)	Any particular problems.	

2.4.3 There were several problems, however. Information on the stretcher trolley use varied between individuals and depended very much on personal experience, but despite this a pattern of problems emerged though some became so repetitive that they were assumed to be common to all situations. It was found that initially the official version of the trolley use was given by ambulance crews which, however, proved different from subsequent information and observed use. This produced a false impression at first but once aware of the problem it became possible to obtain the relevant information from crews using revised questions.

2.4.4 Response to questions varied between stations, but in all cases there was an initial 'blank' period where no problems could be identified as the crews were unaware of any difficulties because of their familiarity with and adaptation to using the trolleys. However, when crews became aware that certain problems occurred at other stations they became more forthcoming about their own observations. For instance it was found that at one station where initially the response was the official version, on repeated visits information became more readily available as the crews became familiar with the author's presence and more aware of the handling process used and difficulties originally taken for granted. They began to note incidents where problems had arisen or areas where they felt improvements could be made. It was also found that information was more readily given when observing in the ambulance as the crews could then demonstrate the point raised. However, the level of observation by crews varied between stations and some had given a great deal of thought to their problems whereas others had accepted them as part of the job.

2.4.5 Participant observation was found to be a very valuable way of obtaining information especially on general handling procedure. However, there were certain problems with observing during '999' duties. Discretion had to be used with the observation of certain cases where emotional upset to the patient and relatives was greater than normal. It was very difficult to observe more than the general procedure at first and subsequent visits were devoted to observing one or two specific handling processes each time. It was found valuable to learn by actual handling of the trolley but almost impossible to observe others while doing it oneself. Each case is slightly different, therefore, the handling procedure varied as well and it was not possible to use repetitive actions for verifying any observations. However, it was possible to observe the casualty during the ambulance ride and the relationship of the trolley to the ambulance bodywork and the problem arising from this.

2.4.6 The casualty and trolley handling demonstration proved invaluable in giving an insight into the feelings of a casualty on being wheeled, picked up and carried. However, it was not possible as a casualty to observe the handling actions other than by feel. It was also found that the demonstration tended towards the 'official version' and not to the actual 'use' methods, but it was still an invaluable exercise in the format for the basic casualty handling procedure.

2.4.7 The information gathered during these visits was recorded in note form at the interview and during observation, then expanded into a process report for each visit. One report has been given in Appendix B as an example of the information collected and the method of recording it. Photographs were taken of the casualty and trolley handling demonstration but it was decided that there would be too many difficulties involved in photographing 'use' situations as most observation was done during evening or night shifts.

2.4.8 Perhaps the hardest problem to overcome in this information gathering period was the initial reluctance of the crews to demonstrate anything other than the official method, partly through an understandable reluctance to reveal any deviation from the official rules and through fear that this would be reported back to the management. This was only overcome in some instances by travelling with the ambulance and questioning while in transit and in other cases by the sympathetic understanding of the superior officer on the station. Once crews felt that they could speak without fear of rebuke their information was more readily given.

3 DATA ANALYSIS

3.1 Introduction

3.1.1 The information gathered during the data collection period required allocation to the appropriate subject area and collating into an order of importance. This was partly achieved during the collection period, by referencing in the appropriate filing system. However, further sorting and analysis was still required to extract all the relevant details that would allow an overall understanding of the process involved and specific problems encountered. The analysis aimed to discover in detail the user relationship with the trolley so that from this a performance specification could be developed.

3.2 4. Analysis

3.2.1 In order to understand the problems identified relating to the trolley and to ensure that the new design is compatible with the demands that will be placed on it, it is necessary to identidy comprehensively:-

1) The persons using the trolley
2) The places in which is is used
3) The processes involved

This forms the basic ergonomic framework against which the problems identified in the information search can be assessed. The following section, therefore, identifies in detail the users, places and procedures for the stretcher trolley during its service in the ambulance. The procedure however, only relates to the ambulance journey to an accident/emergency, to the hospital and back to base. It does not involve maintenance and cleaning. Maintenance is carried out either in the area workshops or at the manufacturers and cleaning is carried out in the station.

3.2.2 <u>General usage</u> (after sale to Ambulance Service)

<u>People</u>

1) Ambulance crews
2) Hospital staff?
3) Cleaners
4) Maintenance crews
5) Patient

<u>Places</u>

1) In ambulance
2) Roadsides/hard surfaces
3) Fields/soft surfaces
4) Hospital grounds - i.e. loading bays
5) A & E department
6) Lifts/corridors
7) Wards
8) Station grounds

<u>Procedures</u>

A) <u>Sitting cases</u>

Trolley left in ambulance in inner locked position - no blankets - side bars (outer one anyway) down. Arm rests and seat belts available fig.4.

B)i) <u>Stretcher cases</u>

1) Call received
2) Ambulance despatched to the scene
3) " arrives at " "
4) Attendant goes to see the patient and assess the situation
5) Driver joins him to see what equipment is needed
6) Driver returns to the ambulance to fetch the required equipment e.g. splints, blankets, carry chair, or both return to get the trolley out

7) <u>If carry chair</u> - place patient in chair

a) carry out to ambulance and into saloon
b) transfer patient to the trolley
c) put chair away

8) <u>If stretcher trolley</u> - load patient onto trolley

a) adjust trolley to suit
b) load trolley into ambulance - lock into position
c) Further adjustments if necessary - fitting of resuscitation equipment etc.,

9) <u>If using 'Scoop' stretcher</u>

a) load 'Scoop' into ambulance straight onto the trolley.
b) If long journey - remove 'Scoop' - for short journey it stays in place
c) adjustments and resuscitation equipment etc.

10) Drive to the hospital - attendant monitoring in back.

11) Off load trolley - may need to keep resuscitation going

12) Wheel into A & E department and transfer to hospital trolley or - register patient in admissions
Wheel into ward (may need to use lift) and transfer to bed (fixed height in coronary case dept)

13) Remake trolley bed and retrieve equipment

14) Re-load empty trolley into ambulance

15) Write up log sheets etc. - report clear to Control

B)ii) Hospital transfers

1) Ambulance to hospital
2) Off load trolley
3) Take it to the ward
4) Load patient and accessories if any
5) Collect patient's belongings unless a nurse is also travelling
6) Take patient out to ambulance
7) Load into ambulance and lock into position
8) Adjust for comfort and any equipment needed
9) Drive to second hospital - attendant and nurse or doctor et., monitoring patient in back
10) Off load trolley
11) Wheel into required ward
12) Transfer patient to hospital trolley, bed
13) Remake trolley
14) Re-load ambulance with trolley
15) Report back to control

3.2.3 Once the individual areas had been identified it became appropriate to discover the relationship between them by identifying firstly the people associated with each phase of the procedure then relating this to the places. The first of these steps is given below.

A) Sitting cases (90% - 94%) of journeys

Procedure	People
Trolley in ambulance	Patient
No bedding	Ambulance crew
Used as a bench	

B) <u>Stretcher cases</u> (6% - 10%) of journeys

Basic process	People
1) Call received	Crew
2) Ambulance to scene	
3) Attendant to casualty	
4) Assess the situation	Patient
5) Notify driver what equipment needed	
6) Driver takes equipment to casualty - may need attendant if using trolley	
7) Load casualty into equipment	Crew & patient
8) Carry to ambulance	possibly
9) Load into ambulance	nurse or
a) load into trolley-	doctor if
- if chair	available
- if scoop	
10) Adjustments - additional equipment e.g. Entonox or O_2	
11) Continue 1st aid	Crew,
12) Monitor during journey	patient,
13) Ambulance to hospital	doctor, nurse if avaialble
14) Offload trolley onto loading bay/ground	Crew,
15) Wheel to required ward	patient,
16) Offload onto hospital equipment	nurse

Basic process	People
17) Retrieve ambulance equipment and remake ready for use	
18) Return to ambulance	Crew
19) Reload empty trolley into ambulance	
20) Report to control	

3.2.4 Secondly the relationship between the users, places and handling procedures during the ambulance usage can be summarised as follows:-

Process	Place	People
1. Situation assessment	In ambulance, house, factory, field, roadside, buildings etc.	Ambulance crews, patient, by-standers, doctors, nurses.
2. Journey preparation	at scene - from scene to ambulance - in ambulance	ambulance crew/ patient
3. Journey care	in ambulance	ambulance crew/ patient, doctor/ nurse.
4. Transfer to hospital care	ambulance, hospital, loading bay, corridors, lifts, wards, A & E dept.	ambulance crew/ patient, hospital staff.
5. Equipment preparation	Hospital ward, A & E dept., supply room, ambulance.	ambulance crew.

The trolley is only used during steps 2 to 5

3.2.5 The casualty handling procedure was examined in greater detail by participant observation as 'casualty' during a handling demonstration and this is illustrated in figs. 4 to 27. They show the

Fig. 4

The stretcher trolley in the inner (sitting) position in the ambulance. Note the missing side arm.

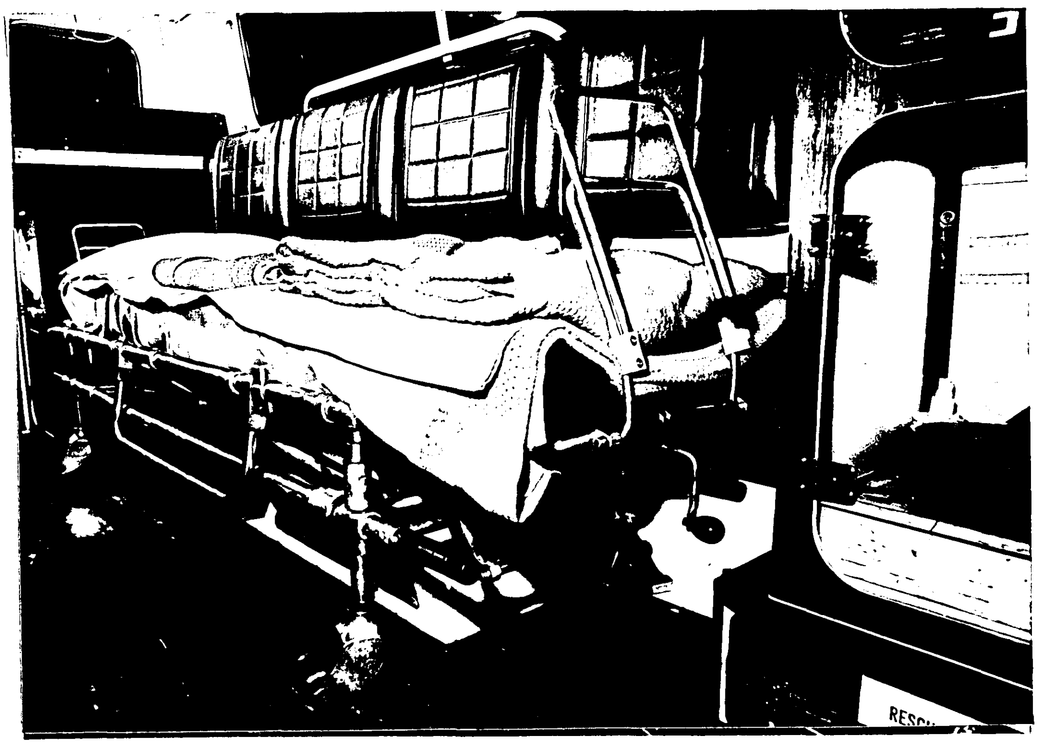


Fig. 5

The prepared trolley in the outer (nursing) position. Note the bent towing handle.

Patient Handling Process

Step 1. The patient on the carry chair is loaded into the ambulance and then transferred from the chair to the stretcher trolley. Note the difficulty of lifting backwards up the steps and the limited room for moving within the ambulance.

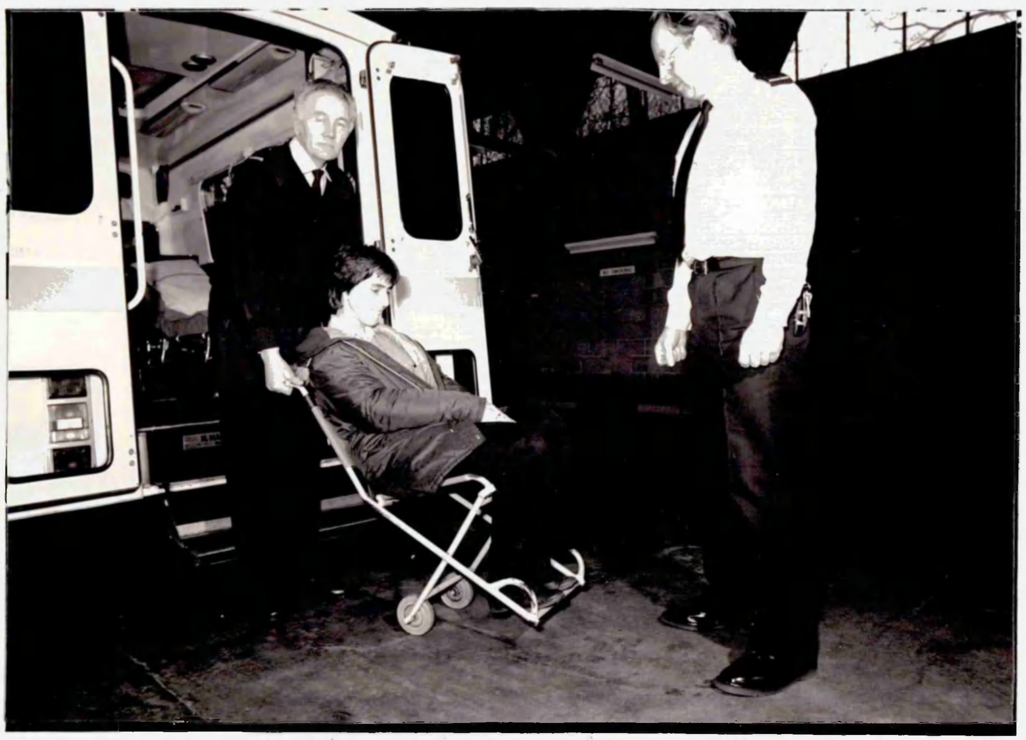
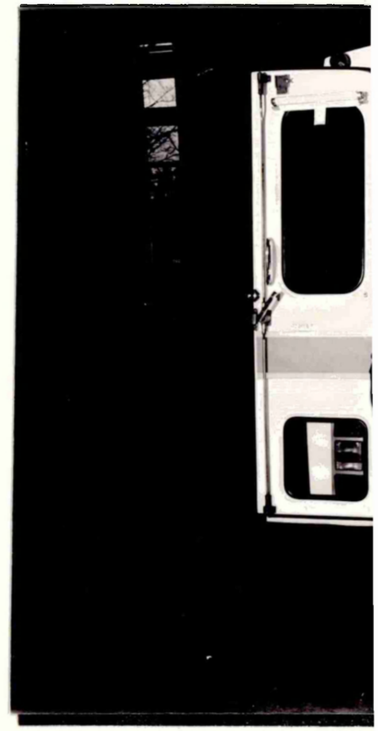


Fig. 6



Step 2. The patient on the stretcher trolley is off-loaded from the ambulance using the side-loading method of handling.

Fig. 11

Step 3. The stretcher trolley is towed into the accident and emergency ward and the patient transferred to the hospital trolley. Note the awkward length of the towing handles and the height to which the patient has to be lifted onto the hospital trolley.

Fig. 14

Fig. 15

The alternative loading method - the end loading procedure. The un-comfortable position of the ambulanceman at the head end can be seen. Note also the deflection in the trolley frame.

Fig. 18

Fig. 21

Elevating the trolley. The position of the ambulanceman's foot on the lower rail can be seen.

The trolley is wheeled in the elevated position into the casualty department where a slide transfer to the hospital trolley is carried out. This was quite comfortable.

Fig. 22

Fig. 25

Using the pole and canvas stretcher to transfer a patient. It felt like being caught in a pair of giant nutcrackers!

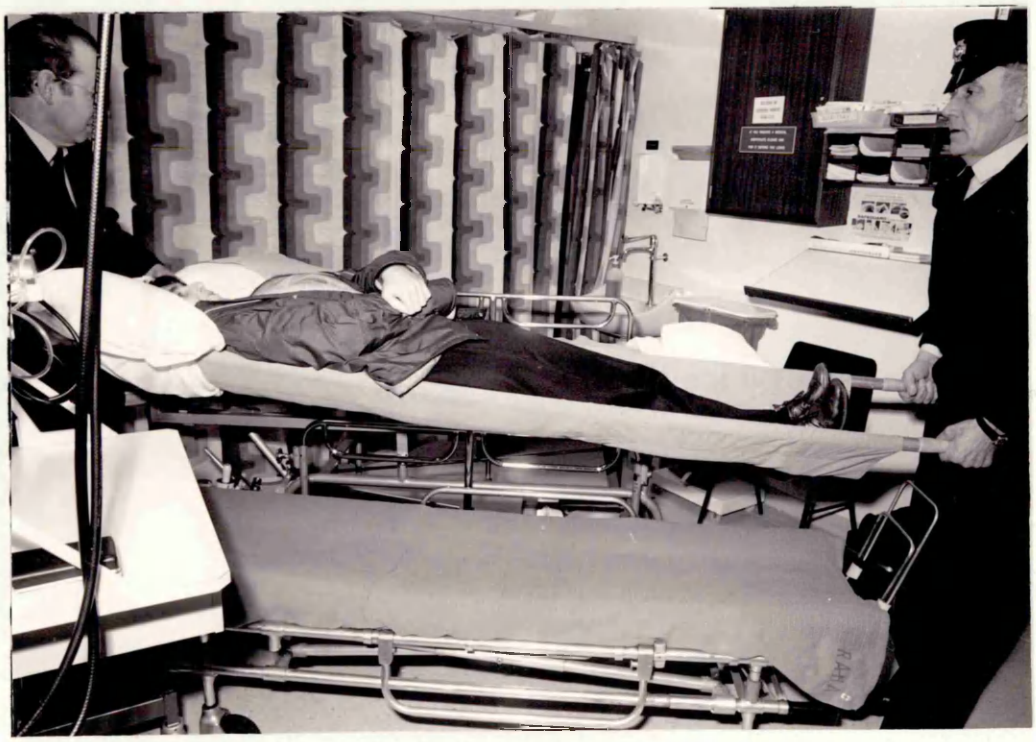


Fig. 26

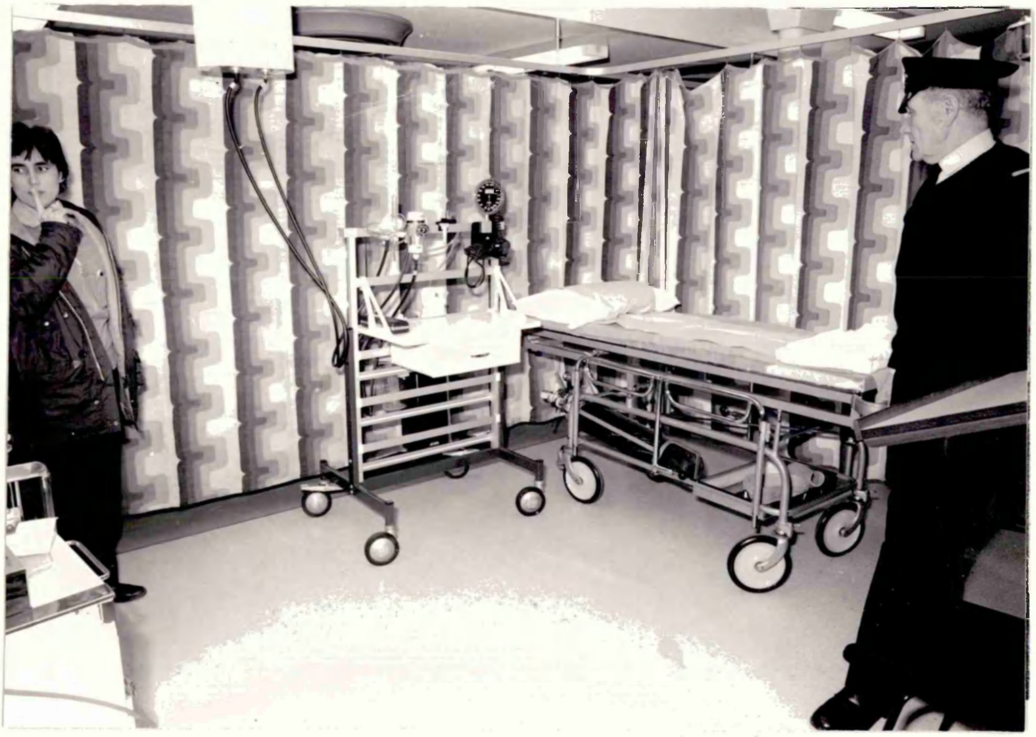


Fig. 27

This shows the layout of an accident and emergency cubicle in a large general hospital. The hospital trolley used here is a fixed height and carries an oxygen cylinder.

complete handling of the trolley and casualty by ambulance crews in most of the positions likely to be used during emergency work. They also show some of the awkward positions and handling lifts that are required and demonstrate the advantages of using an elevating trolley.

3.2.6 Although the use of the trolley by hospital staff was mentioned in one report which found that in some areas ambulance crews are not allowed into the hospital wards and consequently the trolley is taken in by the nurses who then have difficulty in operating the various features. However, it was not possible to verify this by personal observation because of the difficulty of obtaining access to hospital premises.

3.2.7 This analysis provided the ergonomic framework against which the problems identified during the information search were evaluated. It also formed the basic structure for the development of the performance specification against which both the existing trolley and the new design solutions can be assessed.

3.3 5. Problem identification

3.3.1 From the process reports it was possible to extract the problems identified and to tabulate these against the visits made to obtain an indication of their frequency of occurence. This is shown in Table 2 and demonstrates that though some frequent problems have serious implications, others have mainly annoyance value but are equally important to the comfort of both crew and patient. However, some problems occured so frequently that they were not recorded at every visit but were assumed to be present. All the major problems identified are discussed below in groups relative to the different functions or components of the existing trolley design.

Table 2

The following problems were identified during the research from the visits made. They are rated against the existing trolley and the ergonomic framework under the following headings and are listed in chronological order:-

Dangerous - ****
Ineffective - ***
Difficult - **
Discomfort - *

The visits are numbered as in Table 1

Rating	Problem identified	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
**	Elevation use	x						x		x			x	x	x		
****	" stability	x				x			x	x						x	
**	Locating in ambulance	x	x											x			
**	Towing handle	x	x		x	x	x		x	x		x	x	x	x		
****	Telescoping handle caps	x	x			x							x	x	x		
****	Elevation control & lock	x	x		x			x									
*	Mattress - cold	x				x											
****	" slippery													x			
**	" cleaning												x				x
***	Use with other stretchers	x					x										
**	Patient handling from building		x														
*	Trolley dimensions		x			x											
***	Side arms		x		x				x			x	x	x			
**	Ambulance trolley locks		x				x			x							
****	Backrest slipping		x	x				x					x	x	x		
**	" control							x					x				
*	Telescoping handles operation		x			x							x	x			
*	Telescoping handles wear					x											
****	Telescoping handles		x											x			
**	Telescoping handles length		x											x			

Rating	Problem identified	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
***	Fowler position-handle operation		x		x	x	x			x			x	x	x		
***	Fowler position-handle position											x					
**	Maintenance - cleaning								x								
*	Trolley flexing		x							x		x	x				
***	Wheel locks			x		x		x		x		x	x	x			
***	Trendelenberg position					x	x			x		x	x	x	x		
****	Weight					x	x							x	x		
***	Access to patient					x											
***	Access to controls					x	x						x	x	x		
*	Side-loading grease								x				x	x	x		
***	Carry handle position							x									
****	Patient security		x						x			x	x	x	x #		
**	Infusion bottle - use of									x	x	x			x		
**	Patient retaining straps									x		x	x	x	x		
**	Oxygen bottle holder		x								x	x	x	x	x		
**	Wheel dimensions											x	x	x	x		
**	Ride over ground											x	x		x	x	
**	Cardiac monitor/ defibrillator													x			
*	Blankets catching													x			
***	Tension pins loose													x	x		
***	C.P.R. mattress also #														x		
****	Side arms - padded														x		
***	Hyper-extension														x		
***	Ride in ambulance															x	
***	Height in ambulance																x

Fig. 28

The trolley has been pulled out to show the wheel arch and heating unit which it has to fit over. The locking bar can also be seen at the back under the backrest unit.

Fig. 29

The trolley has been pulled out to operate the Fowler's position.

3.3.2 General problems

The elevating stretcher trolley is constructed from an aluminium alloy. This provides a relatively light weight material with a good finish that does not require protection, however, when the aluminium wears it produces a grey dust that rubs off onto hands and clothing and eventually aluminium wearing on aluminium will bind, consequently sliding members become dirty and difficult to use after wear. This is a particular problem on the lower frame where the elevating mechanism slides and, though not dangerous, it is inconvenient when the ambulance crew then have to attend to the patient with dirty hands. Problems also arise with the fastening of joints in aluminium and this affects both the manufacture and design of the trolley. For instance, aluminium is difficult to weld yet it is necessary, because of the telescoping carry handles, to tack weld the wheel castings to the lower frame. These welds are weak and liable to fracture as shown by the number of trolleys returned for repair with this fault. Mechanical fixings also have problems as steel being harder wears the aluminium and consequently fixings such as tension pins work loose and drop out. This can result in loose castings and missing components. For example, fig.4 shows a trolley with the side arms missing.

3.3.3 The relationship between the ambulance body and the trolley causes many problems. A lack of co-ordination between body builders, ambulance officers and the trolley manufacturers for a variety of reasons, has resulted in the space allocated to the trolley being reduced to the extent that it is not possible to use certain handles to operate some of the features while the trolley is in the ambulance. This is illustrated in figs. 28 & 29 where fig.28 shows the wheel arch and heating unit over which the trolley is fitted.

It also shows the limited space avaiaiable to take the trolley. Fig.29 shows the operation of the Fowlers position which because of the lack of space the trolley has to be released to operate it. It is also disturbing that no accommodation is being made for the general increase in size of the population. People are growing taller and heavier and it is difficult to accommodate a 6' man on the existing trolley as his feet project over the end, and the situation is aggravated where the casualty has his leg encased in a full leg plaster with a heel. These cases are difficult to handle and can in some cases only just be accommodated in the ambulance. Similarly there was concern that the present width of the trolley is too narrow and causes discomfort to the larger patient, particularly women with larger hips. The severe lack of working space around the trolley restricts access to the patient and limits the use of other types of stretcher which could otherwise be placed on the trolley. For instance, it should be possible to leave a patient on a Ferley stretcher on top of the trolley to reduce the number of transfers between equipment but this is not possible as the Ferley stretcher handles project beyond the trolley ends and will not fit into the space provided.

3.3.4 There are other difficulties arising from the use of the trolley itself. Concern was expressed about the flexing of the frame but this is within the tolerances set out in BS. 896 (19). There were complaints about the blanket falling through the longitudinal framework of the trolley top and snagging in the elevating mechanism and the difficulty of cleaning this mechanism. There was also a complaint about the difficulty of identifying the head and foot ends of the trolley as there is a risk of placing the patient on the wrong way round should the trolley be reversed in the ambulance. However, the weight of the trolley

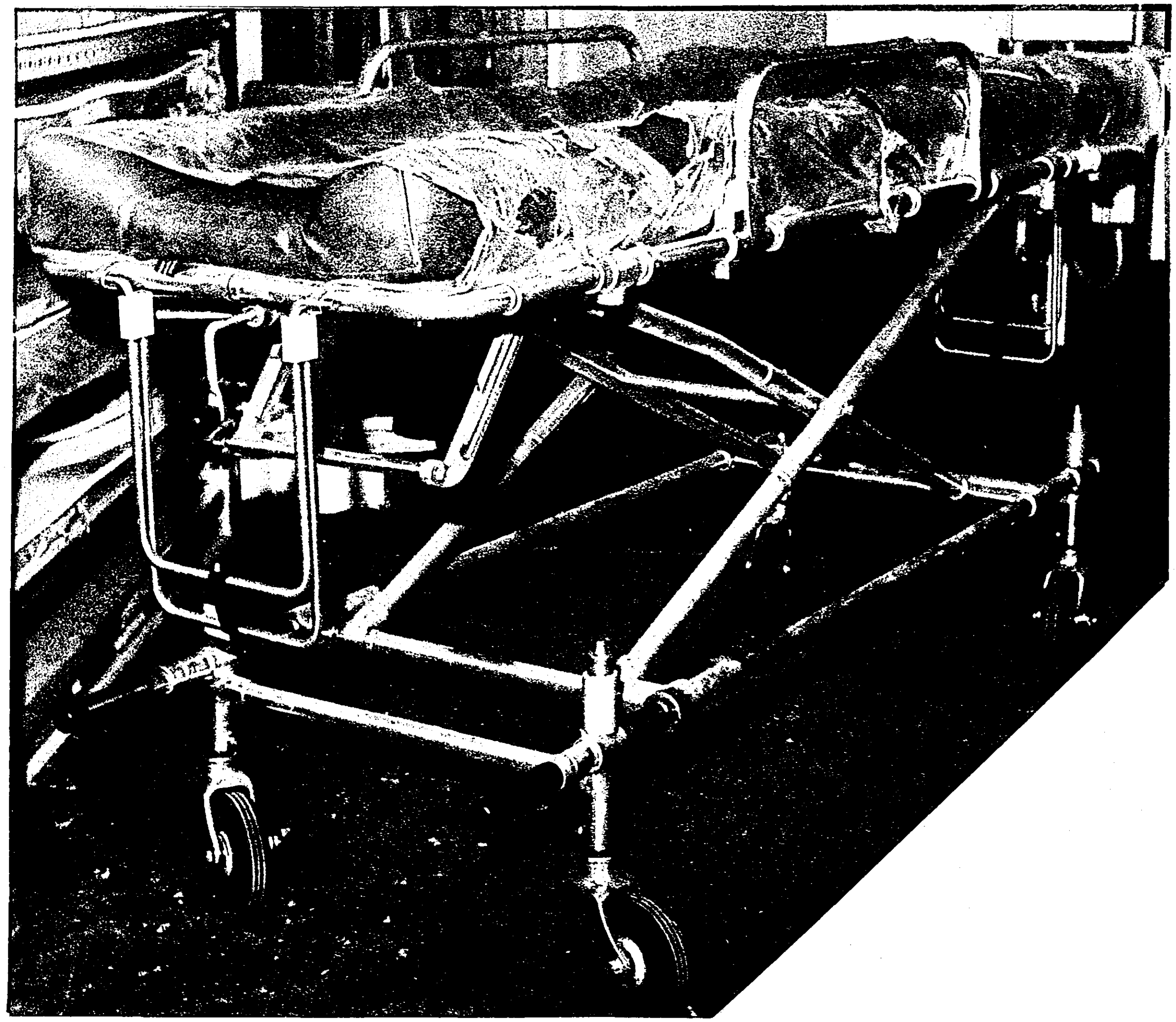


Fig. 30

This shows the 'Super 4' trolley in the elevated position demonstrating the scissor mechanism.

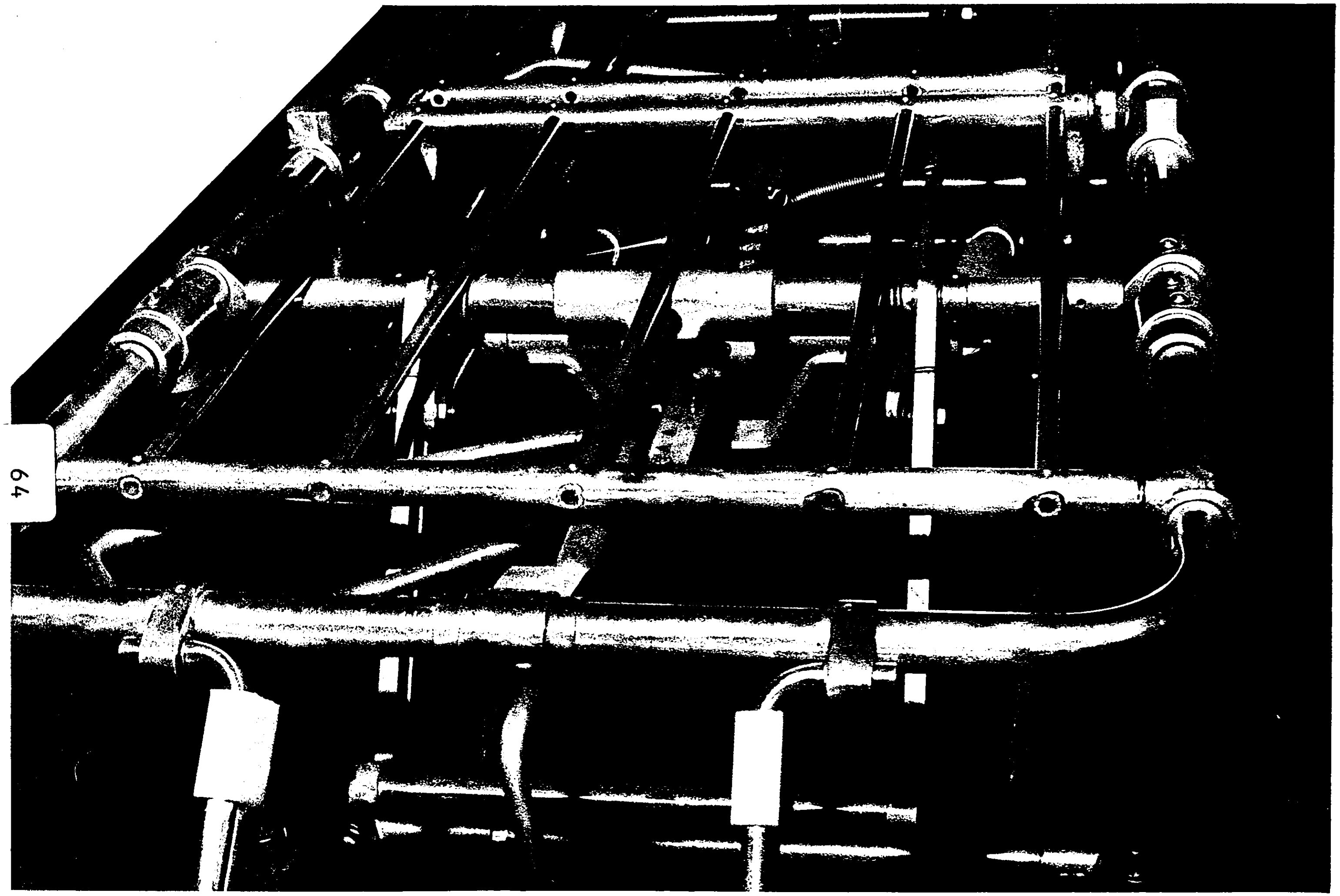


Fig. 31

The ratchet operating bar is shown where it is attached to the foot end handle. The pin is contained in the casting under the Fowler's position screw bar.

was perhaps the most frequently mentioned problem. The elevating trolley is heavier then the non-elevating models and when added to the weight of the casualty the total weight is considerable. It is impossible under these dircumstances for a two man crew to remain within the recommended lifting limits and should something go wrong during the lifting process it is possible that a crew member would risk injury.

3.3.5 Elevating Mechanism

This consists of two pairs of legs pivoted at the centre to form a scissor type mechanism as shown in fig.30 and controlled by a ratchet located under the top frame as shown in fig.31, which enables the trolley bed to be locked at various heights. When used in the elevated position there is better control over the movement of the trolley and it enables the ambulance crew to maintain contact with their casualty which can be lost when the trolley is towed at sitting height. Wheeling the trolley at the elevated height was found by Woodham (7) to give a more reassuring feeling to the patient than when they were wheeled at floor level. Unfortunately, however, due to an incident while in use the utilization of the elevating position when wheeling the trolley from the ambulance into the hospital has been banned in some areas. Crews are still allowed to use it to assist in the transfer to the hospital trolley in the casualty department, but are unlikely to do so as they feel this involves an extra lift. However, it was possible to obtain information on the problem from crews who still use the elevating mechanism or who used it before the ban was imposed.

3.3.6 The stability of the trolley when elevated caused concern in many crew members who felt that it did not appear stable enough. One ambulance man stated emphatically that having used the elevating

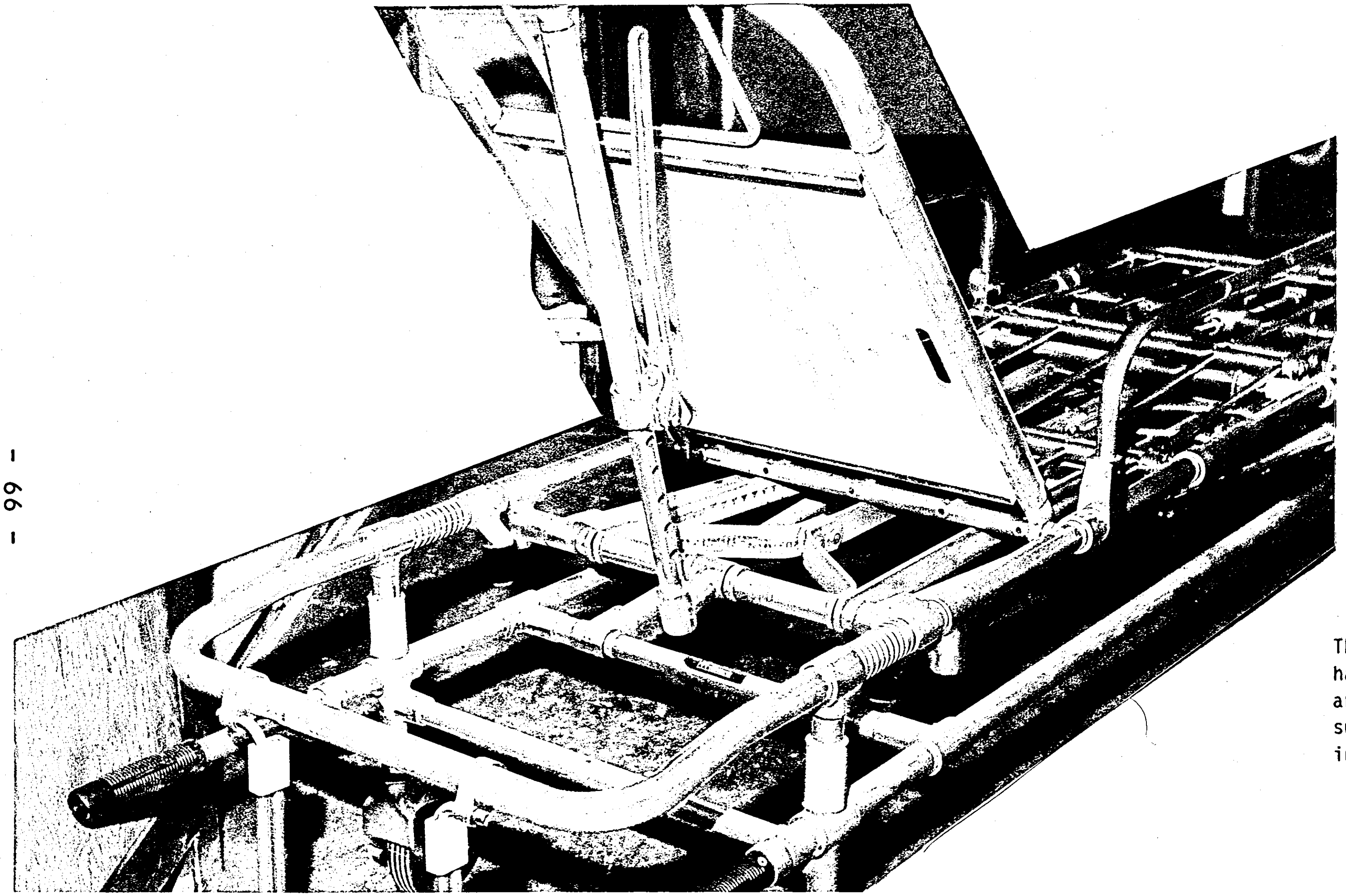


Fig. 32

The backrest support and operating handle. This shows the pin lock and the casting attaching the support to the top frame and acting as the pivot.

mechanism to transport a 30 stone man he would never use it again! This weight is excessive for the trolley and most ambulance crews agreed that it was easier to wheel the trolley when elevated and simpler to transfer the casualty between trolleys when the heights were matched. However, there have been problems with control of the elevating mechanism which is difficult to control in descent with a heavy load as the ratchet can skip over the locking pin without locating. The ratchet can also slip when worn or seize up if the locking pin shears. The control of the elevating mechanism is further complicated by the two operating handles. Of these, one at the side is usable except when the trolley is in the Trendelenberg position, though it is sometimes stiff and difficult to release. The end handle at the foot is fragile and easily bent and is usually found pointing down instead of horizontal, it is also subject to damage by the Fowler position handle and slides. When elevating the trolley bed it is necessary to control the trolley lower frame by keeping one foot on the lower side bar. This is a poor lifting position for the crew members and results in the lower bar becoming bowed causing the elevating mechanism slide to bind and problems with the telescoping carrying handles.

3.3.7 Backrest

This is a moving section of the trolley top pivoted at the inner end and supported by a single telescoping tube and pin lock as shown in fig.32. It is used constantly when carrying patients as most like to be supported. However, it is difficult to raise from the horizontal position as there is no access to the handle under the frame so it is usually left in the 2nd or 3rd notch up. There is, however, a very real danger of trapping fingers or hand when raising or lowering the back-

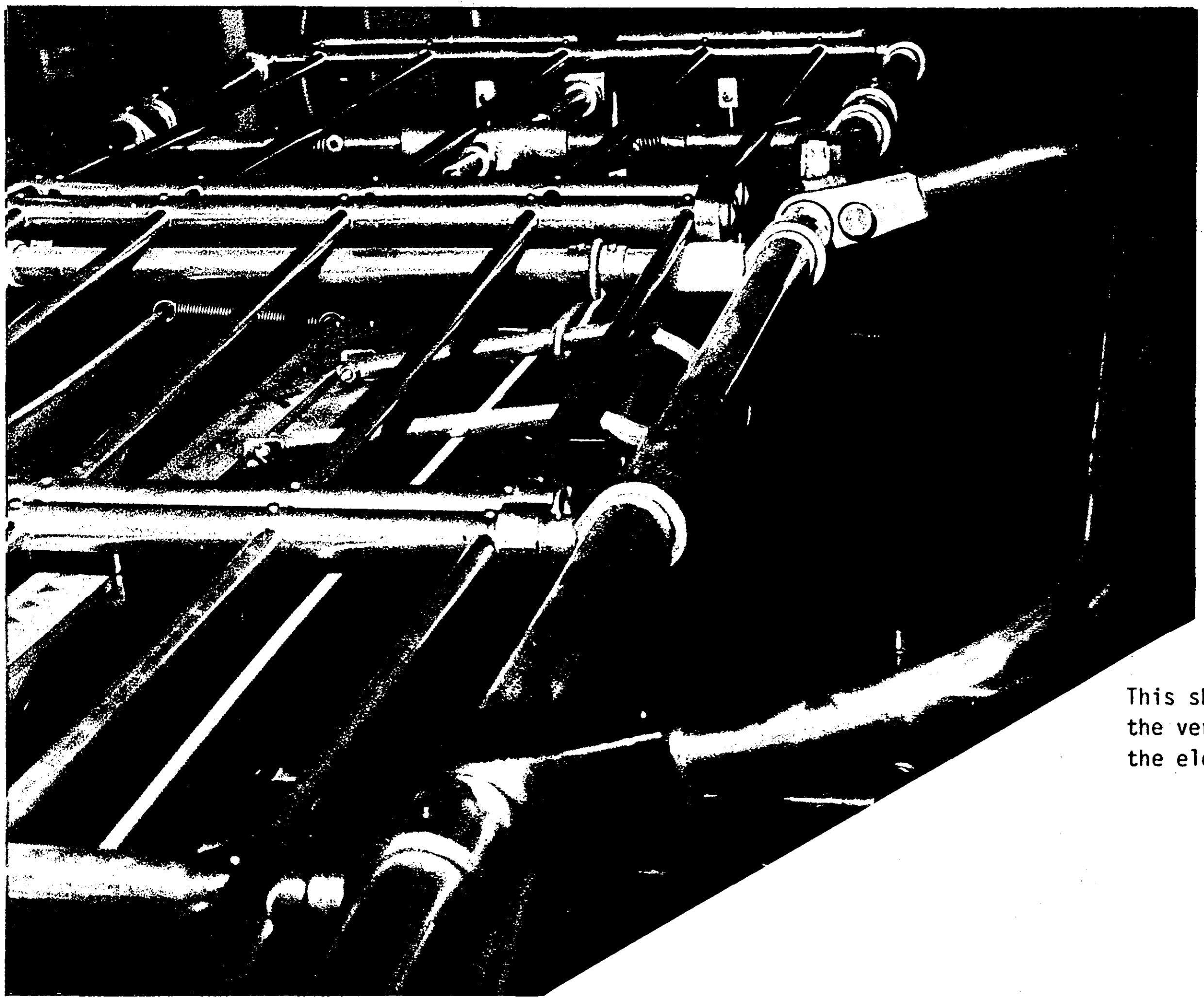


Fig. 33

This shows the side arm during the swing up to the vertical position. The side handle for the elevating mechanism can also be seen.

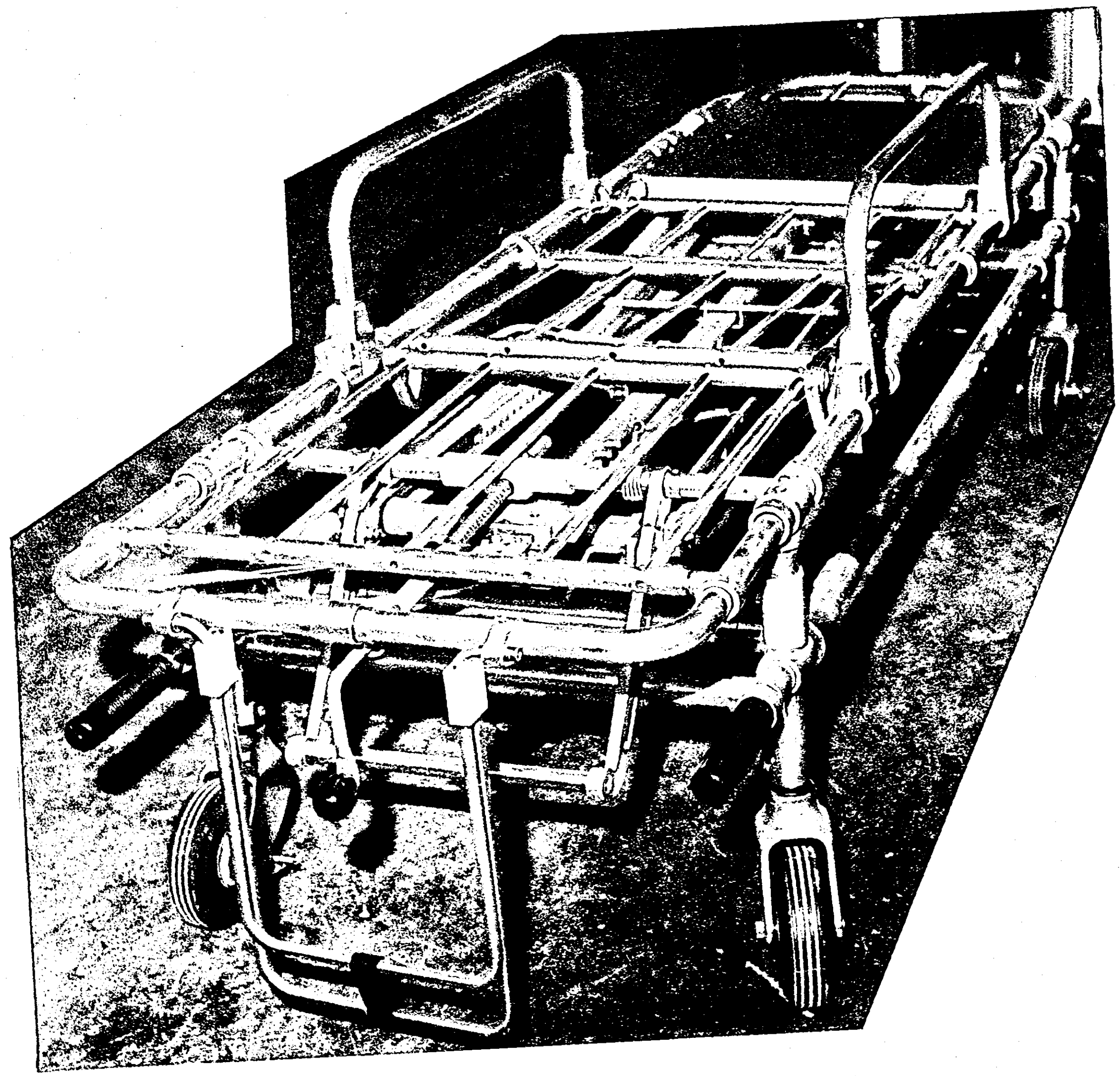


Fig. 34

The side arms are in the patient retaining position.

rest with a weight on it. Due to the single central support, when travelling it has been noticed that there is a tendancy to sideways movement and a bent support pin has been observed. Safety is again a problem and there are reports of the pin slipping when worn, allowing the backrest to fall causing further shock and risk of injury to the patient.

3.3.8 Side Rails

These pivot about the top frame sides as shown in fig.33 and should provide protection to prevent patients falling out sideways. Fig.34 shows the trolley with the rails up. However, as also found by Snook (11) they are neither long enough nor high enough to provide adequate safety for a semi-reclining patient and on discussion of this problem one ambulance man remarked:-

> "We spend 90% of our time holding the patient in while cornering, especially if travelling fast."

When on '999' duties it was possible to observe patients reactions to these and many were found to be nervous either holding the arm or, in one instance, a coronary patient nervously grabbed the rail above the seat back rests for fear of falling out. Another case involved a gynaecological patient in very severe pain who travelled on her back with knees drawn up tight, and had to be steadied all the time to prevent her falling out. There are numerous other examples but the height of the side rails is determined by the design of both the trolley and the ambulance. For example in some ambulances it is only possible to put the trolley in the inner (sitting case) position as shown in fig.4 if the rail is upright as it will not fit over the wheel arch. In other cases the trolley will only go in with the rail down as when up it will not fit under the seat backrest.

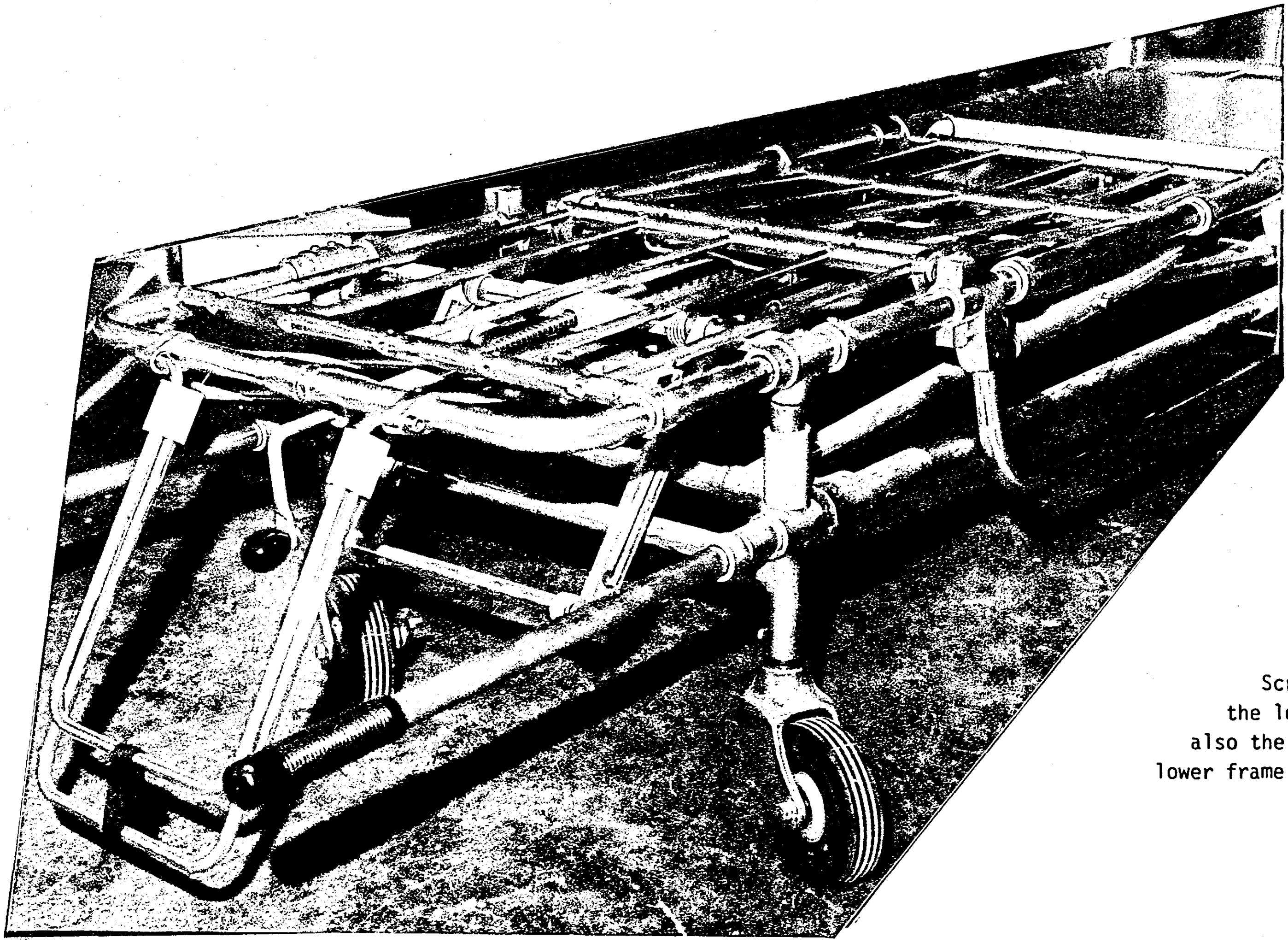


Fig. 35

The carry handles are extended. Screw caps retaining the handle in the lower frame can be seen and note also the side arm resting against the lower frame in its storage position.

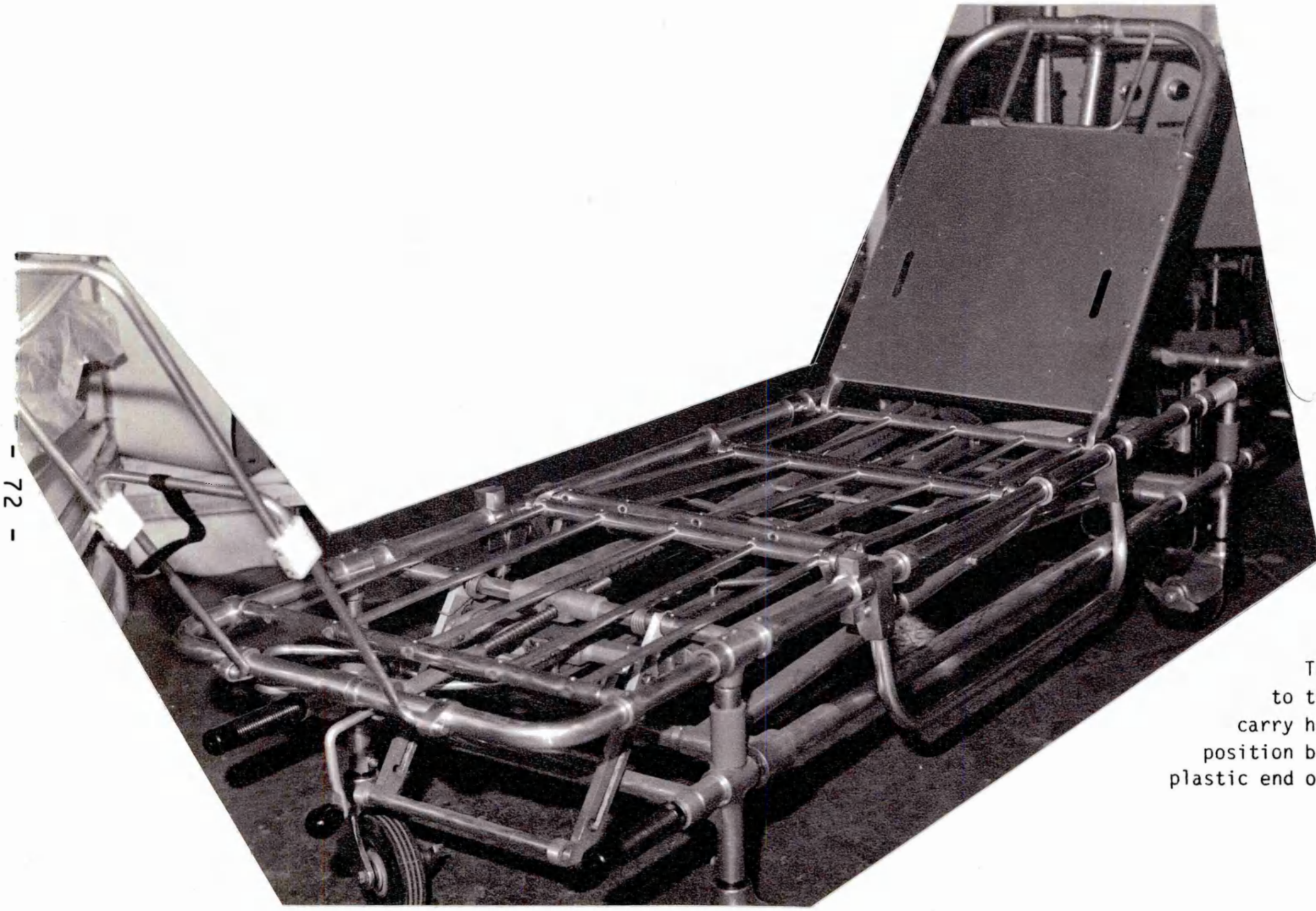


Fig. 36

The towing handles are extended to the pulling position. The carry handles are in the storage position but the rivet holding the plastic end on can be seen.

When down the rail lies against the lower bar of the trolley frame causing a groove to be worn in the frame weakening it and because of this the rails always project out at the sides. This can be seen in figs. 35 & 36. The new version of the elevating trolley carries aluminium sheeted, padded side rails. These create an additional problem in that they restrict the width of the trolley causing discomfort to large patients whereas in the existing trolley the rails are open and parts of the casualty can be accommodated between the sides. Casualties also exhibit increased nervousness as they are unable to find any holding area. The side rails are probably the one component in the trolley of which the patient is most conscious and they cause the greatest display of anxiety and nervousness.

3.3.9 Carrying Handles

These telescope into the ends of the lower frames and one of the major problems with them arises from this. Fig.35 shows the handles extended with the screw caps visible. Fig.36 shows the handles in storage position and the rivet in the plastic handle end can be clearly seen. When the trolley is elevated the crew ususally stabilize it by placing a foot on the lower frame, as demonstrated in fig.22 of the handling excercise, eventually causing permanent bowing. This in turn prevents proper easy movement of the telescoping handles which is made considerably worse by the accumulation of dirt and grease in the sliding units. As a result of this the handles stick causing sudden movement of the trolley and anxiety to the casualty. There are also further problems with these handles resulting from the manufacturing details. For instance there were reports of the caps,fig.35, that retain the handles in the lower frame, working loose allowing the handle to come completely out when pulled. Similarly, the plastic handle ends, fig.35, are retained by a single rivet and repeated wear eventually causes this to fall out and the ends to come off. This always seems to occur when about to lift the trolley with casualty out of the ambulance causing great anxiety to the ambulanceman and the risk of injury to both him and the patient. Considerable concern was expressed over the flexibility of the handles which appear to bend when lifting a load although there have been no reports of failure. The handles can also rotate in the frame and cause a feeling of insecurity which is exacerbated by the construction of the trolley in which the handles are placed below the centre of gravity of both the trolley and the weight on it. This causes a feeling of instability when lifting the trolley from the ends and unless care is maintained during a lift, or should the patient make a sudden movement, there is danger of the trolley overturning.

3.3.10 Towing Handles

These are lightweight tubular handles telescoping within their own length for storage and attached by simple castings to the head and foot of the trolley. When released the handle falls into a vertical position, then when in use it is pulled out to full length as shown in fig.36 and can swivel to any position within 180°. Of the criticisms made and problems mentioned these were the most frequent and though not dangerous they were considered the most annoying. Many of the problems, however, arise from the "misuse" of these handles which are used to lift or lower the unladen trolley into or out of the ambulance, though this is not recommended by the manufacturer, however, they are just the right length for this. These handles are often bent as seen in fig. 5 of the handling exercise

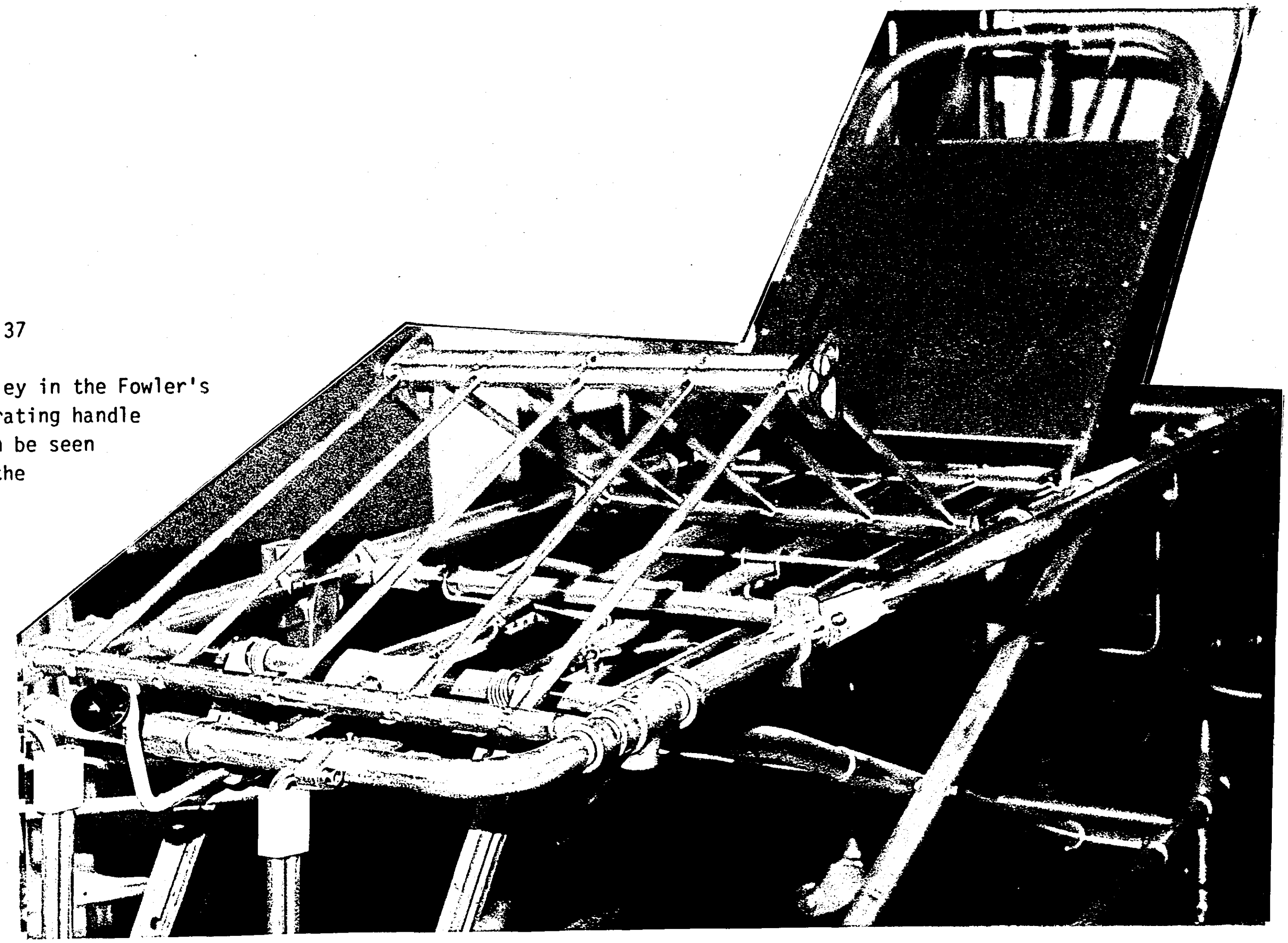


Fig. 37

This shows the trolley in the Fowler's position. The operating handle for this feature can be seen at the foot end of the trolley.

as a consequence of being forced forward against the trolley frame when pushing it. This prevents them from telescoping resulting in further damage as the trolley is used with the handle left extended. They can also be bent as a result of the relationship of the trolley with the ambulance as there is sometimes inadequate room for the handle when down so it is left up. This again is clearly demonstrated in fig.5 of the handling exercise where both towing handles are up. Very often the handle at the head of the trolley has been removed as some ambulancemen complain of it catching on their heels when carrying the head end, particularly when using the end-loading method into the ambulance or when carrying up steps. Complaints were also made that when guiding the trolley round corners the handle can spring out of the castings or, if worn, it can break off. There were also complaints by some crew members that the handles are too short to allow them to stand upright when towing the trolley, but this depended on the height of the crew member involved.

3.3.11 Fowler's Position

The knee contour position is maintained by mechanically elevating a section of the trolley bed using a screw thread operated by a handle at the foot of the trolley. This is shown in fig.37. It was very difficult to assess this feature as it was never used during the observation periods and its use varies between areas. It was reported more often used in areas where the journey times were considerably longer than normal for a call out in an urban area. However, probably the factors contributing most to its non-use are the impossibility of operating this feature once the trolley is in the ambulance because of the lack of room for using the handle. One ambulanceman reported that he had to unlock the trolley to operate this feature, as demonstrated in fig.29, then re-lock

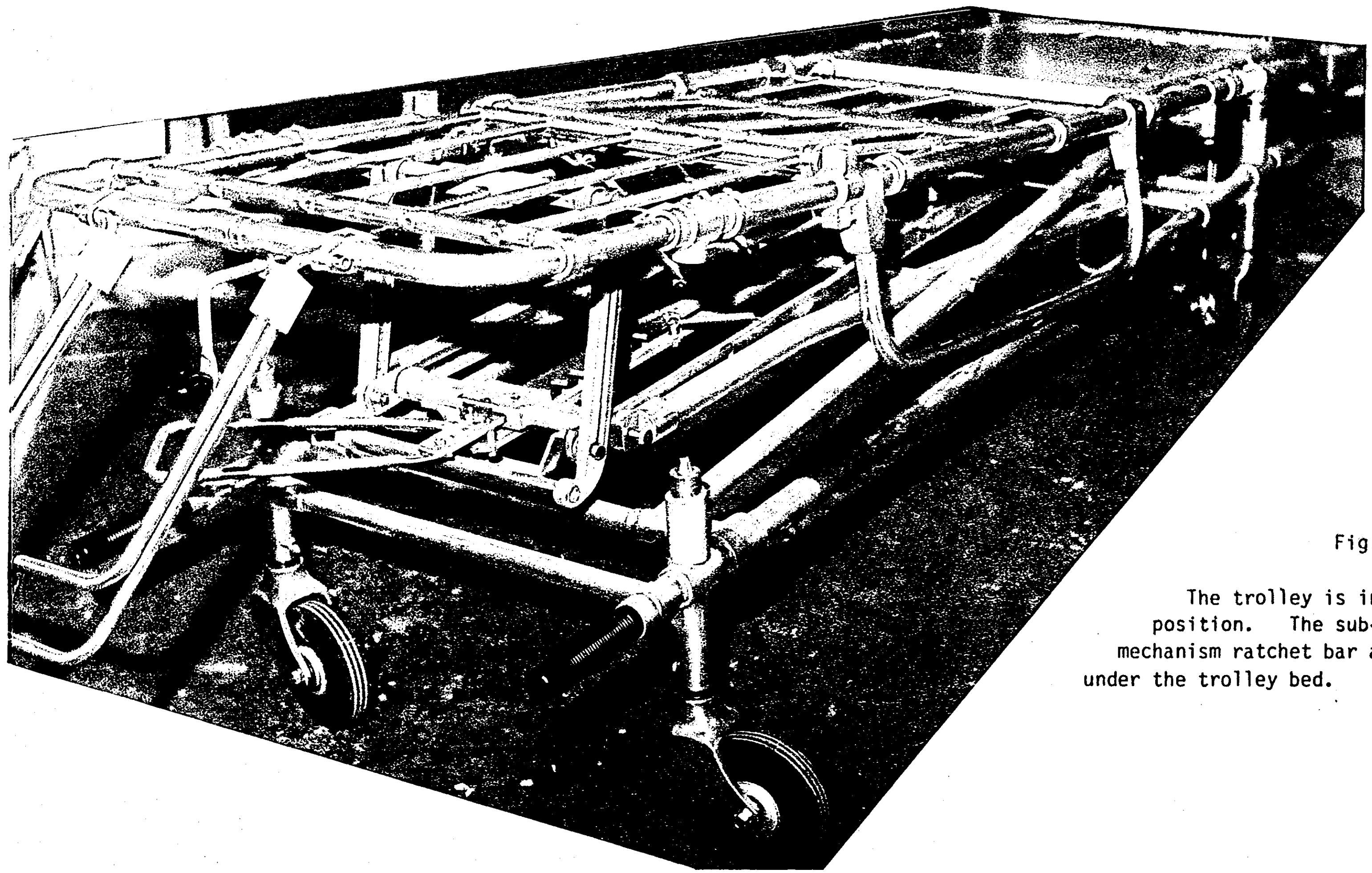


Fig. 38

The trolley is in the Trendelenberg position. The sub-frame and elevating mechanism ratchet bar are clearly visible under the trolley bed.

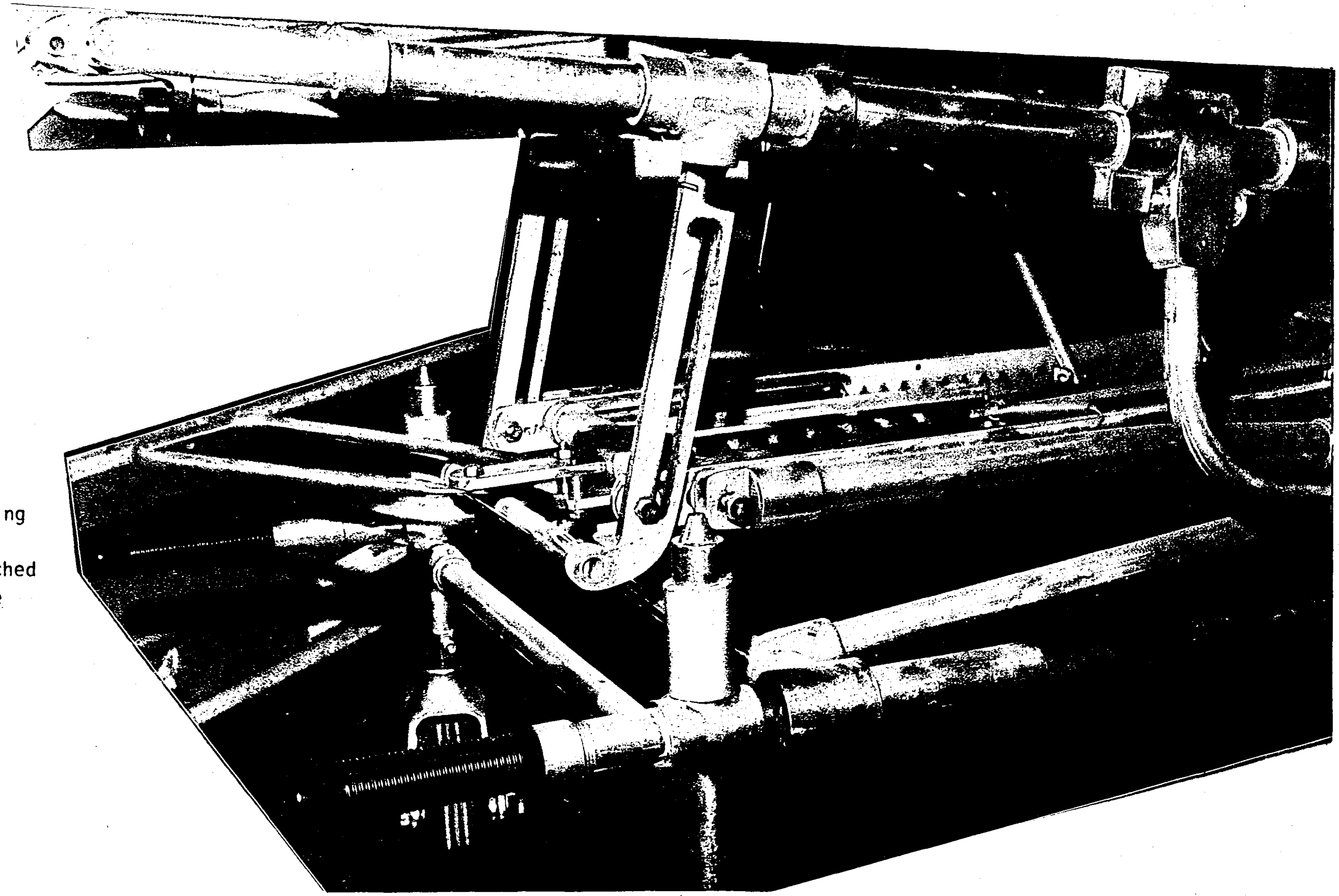


Fig. 39

This shows a close up of the Trendelenberg operating system. The slides and supporting legs are attached to the handle and operate about the sub-frame.

it into position. Others reported that the screw thread is stiff and very difficult to operate while supporting a weight and the operating handle rubs against the towing handle catching the fingers of the operator. Because of these problems, reports suggest that this position is maintained now, where necessary, by the use of rolled blankets. However, this position could be a useful and pain-relieving feature for abdominal or gynaecological cases if properly supported and made usable in a moving ambulance.

3.3.12 Trendelenberg Position

This feature allows the trolley to be tilted at an angle of 10° - 15° to the horizontal, as shown in fig.38, enabling patients with head injuries or who require drainage to be maintained in the proper position. It was again found that this feature is rarely used in some areas but reported used in others where longer journey times are normal. Factors contributing to its probable non-use are again the almost impossibility of operating this feature with the trolley locked into position in the ambulance. Access to the handles is difficult and if worked from one side the slide does not locate and lock properly. Fig.39 shows the support and handle; the closeness of the components can be seen even when out of the ambulance. Fears were expressed that the support could be jerked out allowing the trolley top to drop and there was also concern that casualties could slide off the head end during travel and into the cupboard or bulk-head. This again could be a very useful position for minimizing shock in casualties if made usable in the ambulance.

3.3.13 Cardio-Pulmonary Resuscitation (C.P.R)

This enables the head to be tilted back, as shown in fig.40, to keep the airway clear and provides a

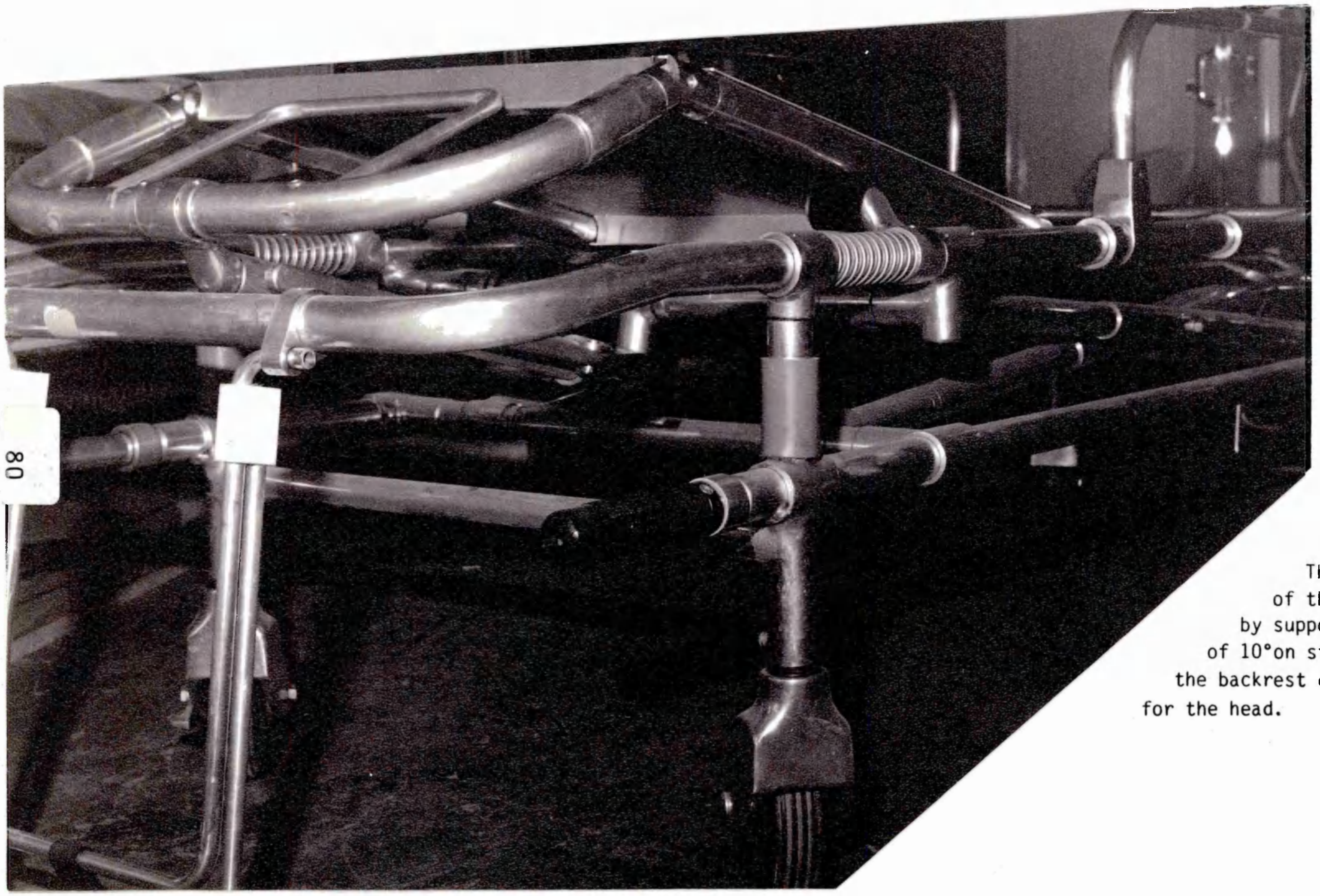


Fig. 40

The hyper-extension position of the backrest. This is achieved by supporting the backrest at an angle of 10°on stops then hinging the end of the backrest downwards to get the tilt back for the head.

hard surface, after removal of the mattress padding, for cardiac massage. It was not possible to evaluate this, however, as it is only available on certain trolleys and observed in only two stations from whom there were no reports of it being used. Concern was expressed that it would take too long to operate as the procedure involved several separate actions and again more use is likely to be made of blanket rolls to maintain an open airway than of the feature provided. Cardiac massage would probably be performed on the ambulance floor as time is vital in these cases. This feature. however, would be life-saving if made easily and quickly usable, as airway maintenance is very important with any unconscious casualty who can suffocate as a result of the tonge falling back unless the head is held back, to keep the tongue forward. McDonald, Bank & Ledingham at (3) found that lack of attention to the airway leading to obstruction and aspiration contributed to the mortality rate. These are preventable factors.

3.3.14 Mattress

There are two types of mattress in use. The normal mattress is contoured and made of dense fire-resistant foam while the C.P.R. mattress for use with the 'Super 4' trolleys with C.P.R. features is flat and thinner. The contoured mattress is used in the majority of ambulances and was reported comfortable although there were some complaints of feeling the bars of the trolley top through the mattress. However, it is very cold and one ambulanceman stated that he found it difficult to achieve some warmth on the mattress even with blankets over it, especially when carrying hypothermia cases. The fluting in the centre of the mattress can be difficult to clean and it is a comparatively heavy component (7Kg) of the total trolley weight. Length is again a problem and it was reported inadequate to accommodate a 6' person. The C.P.R. mattress is only 2" thick against the 2" centre and 4" side of the contoured mattress. It was found easy to clean as it is flat and smooth but there were reports of patients sliding on the smooth surface causing a security problem when travelling. It was considered too slow to use the C.P.R. system as this requires the inner cushion under the head of the mattress to be removed before cardiac massage can be performed.

3.3.15 Wheel Units

The wheels used on the existing trolley are very robust but also very heavy. Ambulancemen reported poor ride over rough ground due to the small diameter (5") and narrow tyre width 1" of the wheels nor is it possible to wheel the trolley on grass or soft ground. The wheels may be subjected to shock loadings when the trolley is dropped out of the ambulance during unladen handling resulting in cracked castings and further weakening the weld between the casting and the lower frame mentioned earlier. However, the main complaint about the wheels when using the trolley, was the ineffectiveness of the brake locks. When worn these brake locks do not hold when required allowing the trolley to roll, nor is it easy to decide from the position of the brake lever whether the lock is on except by using trial and error methods. The swivel feature on the wheels further complicated the use of the brake lock as when the wheel rotated inwards the lock lever became difficult to use. This again is another feature that is rarely used because of the difficulty of operating it and most crews will simply get a bystander to steady the trolley instead of trying to use the brakes.

3.3.16 Accessories

Many crews felt there was a need for facilities to be provided that would enable an infusion bottle or bag to be carried on the trolley, an oxygen or Entonox bottle to be accommodated and in some areas facilities for a cardiac monitor and defibrillator. At present, although accessories are available to accommodate an infusion bottle/ bag and oxygen bottle these are either not provided in the ambulance or if used they can make handling the trolley difficult as they clamp to the side rails. Consequently, if oxygen or Entonox is needed the bottle is carried on the trolley between the patient's legs or at one side and if an infusion drip is set up then an additional person is needed to carry this, ususally a nurse, though it was pointed out that she has other things to do. So far there does not appear to have been any provision made for the use and carriage of cardiac monitors and defibrillators and these have to be accommodated on the patient's legs or balanced on the end of the trolley. It was felt that some provision to accommodate these accessories was necessary but that it should be provided in such a way that the use of the trolley is not impeded, especially as advanced training is enabling ambulance crews to practice more sophisticated techniques and in some areas the use of an emergency doctor service means more immediate aid to the casualty and probably the use of more equipment around the trolley in the ambulance.

3.3.17 There were many complaints about the locking system used for locating the trolley in the ambulance as the operating handle is not easily accessible when the trolley is in position with a patient on it. To reach the handle it is necessary to lean over the patient and under the seat backrest then push the handle down to release the lock. These locks are not always secure and it has been reported that trolleys have become loose during the ambulance journey. Though this affects the trolley use the solution must lie mainly with the ambulance design. Another contributing factor to the reluctance to use the trolley facilities is the lack of standardization in equipment. At one station an ambulance may carry a multi-postural elevating trolley on one side and a simpler non-elevating 3 function trolley on the other or another one may carry only the very basic two function trolley on one side and a 3 function on the other. Consequently when a crew takes out an ambulance unless they are careful to check the type of trolley they are using they may have any one of three varieties all with different combinations of functions. This leaves them reluctant to use any but the basic facilities which are known to be present on all trolleys. Similarly where trolleys with a C.P.R. facility are available there is no co-ordination between this unit and calls to cardiac cases with the result that cases that could benefit from the more expensive equipment are not necessarily carried on that equipment. There is certainly a need for better standardization of equipment on ambulances capable of accommodating all patients or as noted by Murray (18), sooner or later a seriously ill casualty will be placed on a trolley without proper facilities for his accommodation requiring improvisation to do what should be available on a fully equipped multi-postural elevating trolley.

3.3.18 Future Trends

During the collection of data information was sought on the likely future of both the ambulance service and emergency care. It would seem unlikely that any major change will occur in the ambulance service in the near future, though there are moves to bring the two-tier system into use. This would entail an emergency vehicle equipped to handle only emergency cases and carrying a single trolley. Separate transport vehicles less well equipped for emergencies would be used for out patient work. At present am ambulance is equipped for emergency work but doubles as transport for out patient duties. This system would enable the emergency vehicle to be designed and equipped to give the best possible assistance to the seriously ill casualty. Similarly the trolley deaign would need to accommodate the changes in performance and many of the features that at present are avaialble only in accessory form would become standard fixtures. It would also be possible, once the need to accommodate four sitting passengers had been removed, to concentrate on the comfort and safety of the reclining patient.

In emergency care and first aid, however, changes are occurring now in some areas that will affect the ambulance trolley. As stated earlier more ambulancemen are being trained in advanced first aid, particularly in the south of the country, and the use of infusion to reduce shock will probably spread to other areas when its effectiveness is recognised. The use of doctors at the scene of an accident also indicate that more sophisticated equipment will be needed in the ambulance as the emphasis changes from the prevention of deterioration in a casualty's condition to the start of treatment to reduce shock and present the a casualty at hospital in a better condition to undergo treatment than is the case at present. These changes are slow but will, one hopes, gradually become normal throughout the country. The new trolley will need, therefore, to accommodate these changes in the future while still improving existing conditions.

3.3.19 All the above problems were then given a weighting, as shown in Table 2, according to their effect on the casualty, crew and the handling processes

Fig. 41 - PATIENT

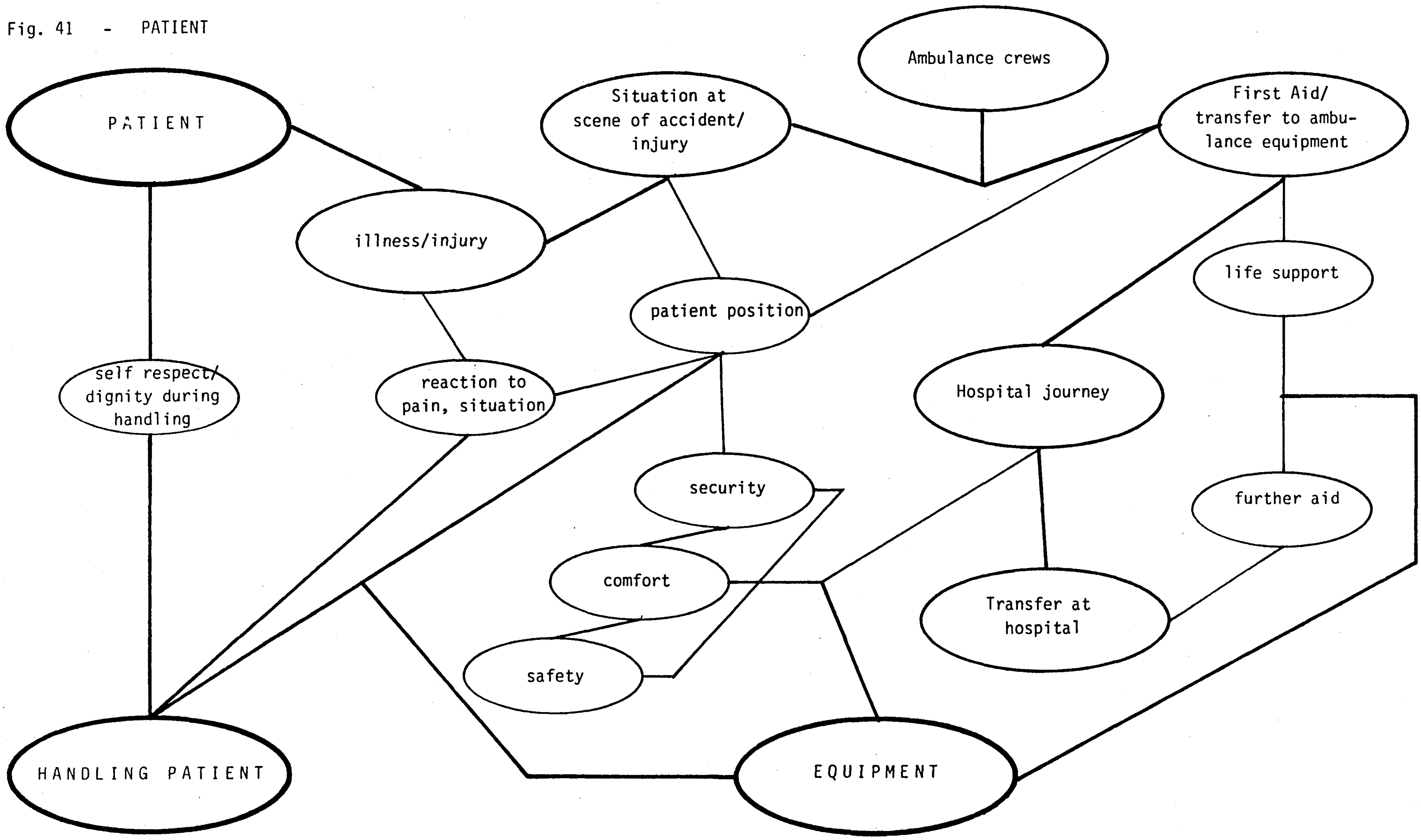


Fig. 42 - AMBULANCE CREWS

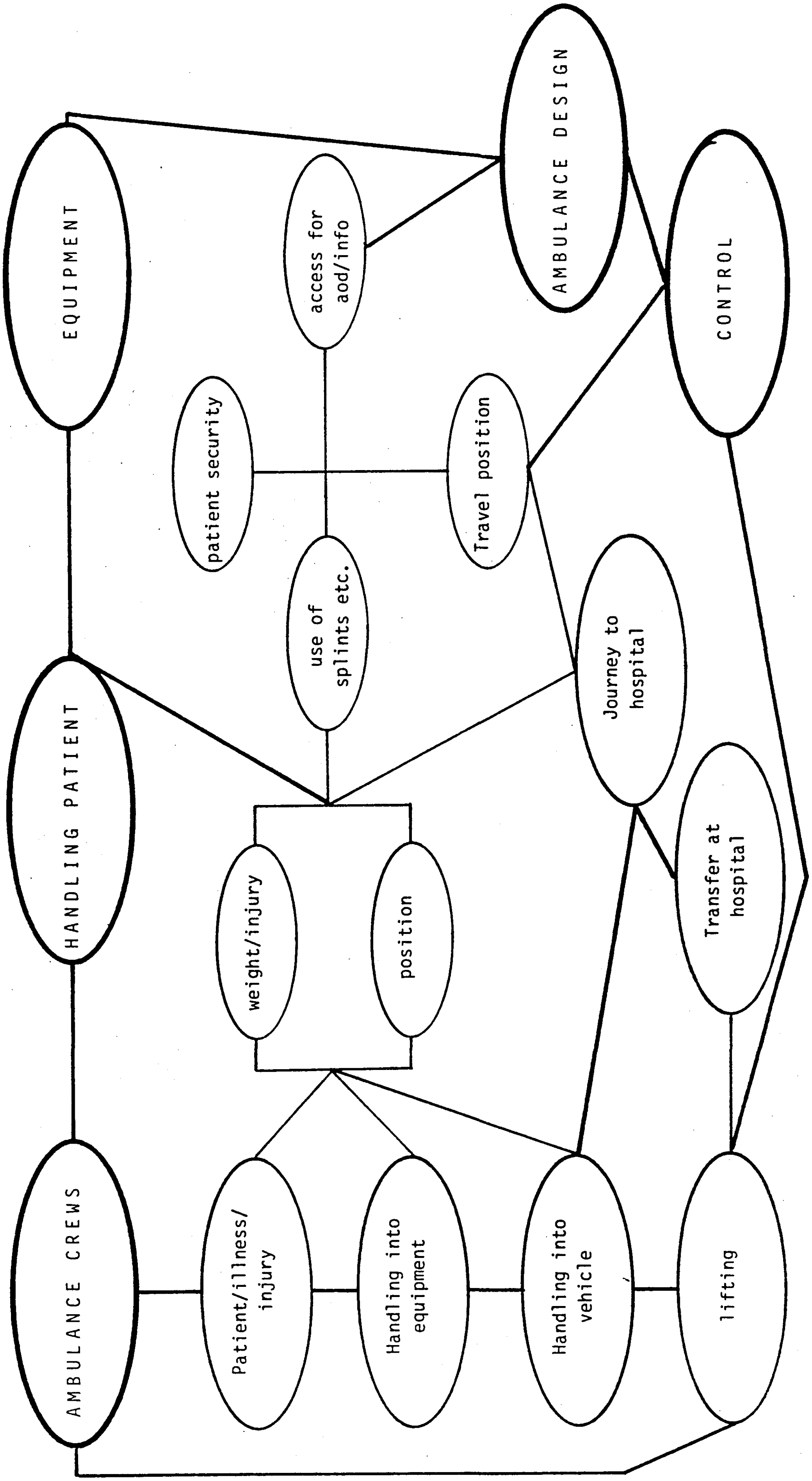


Fig. 43 - HOSPITAL STAFF

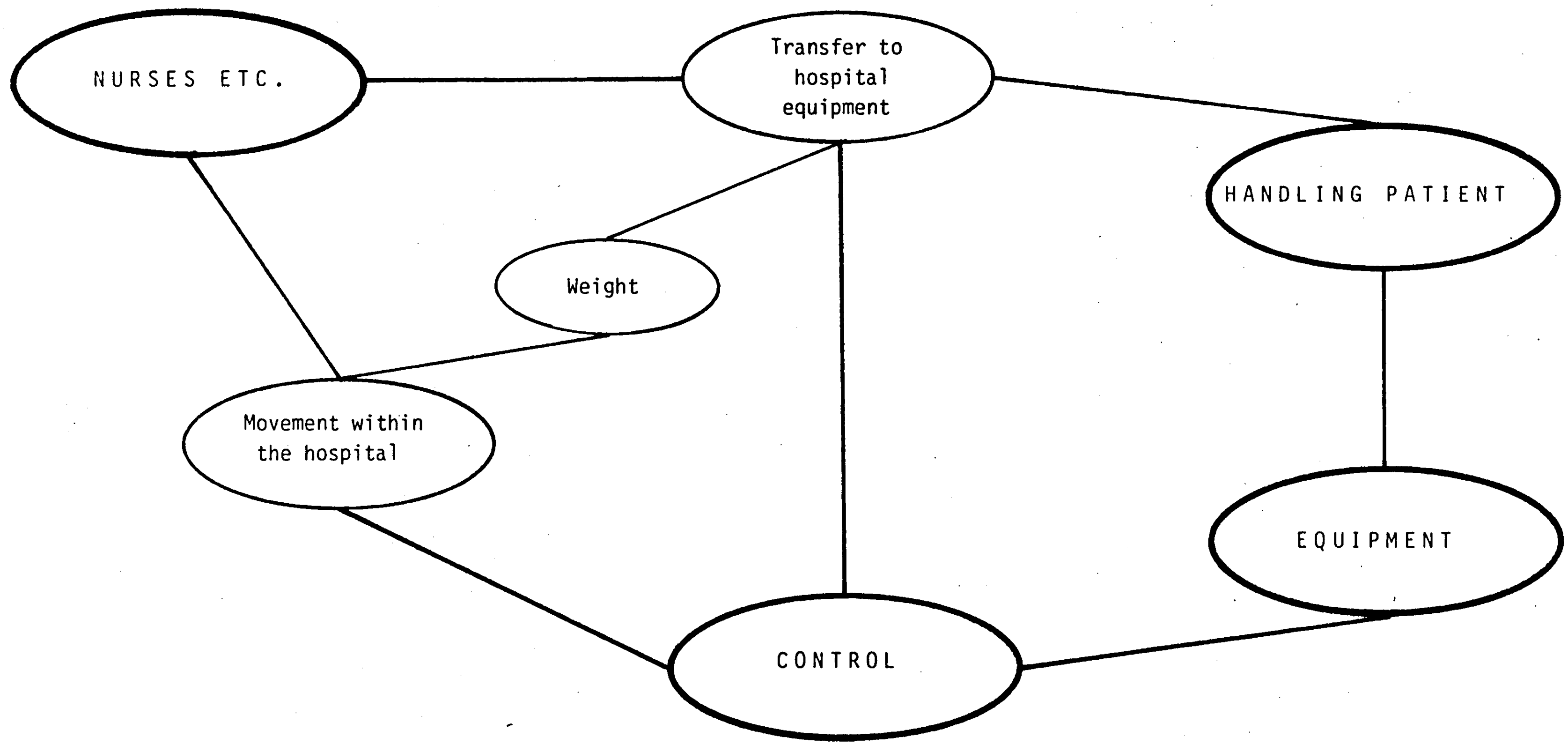


Fig. 44 - MAINTENANCE CREWS

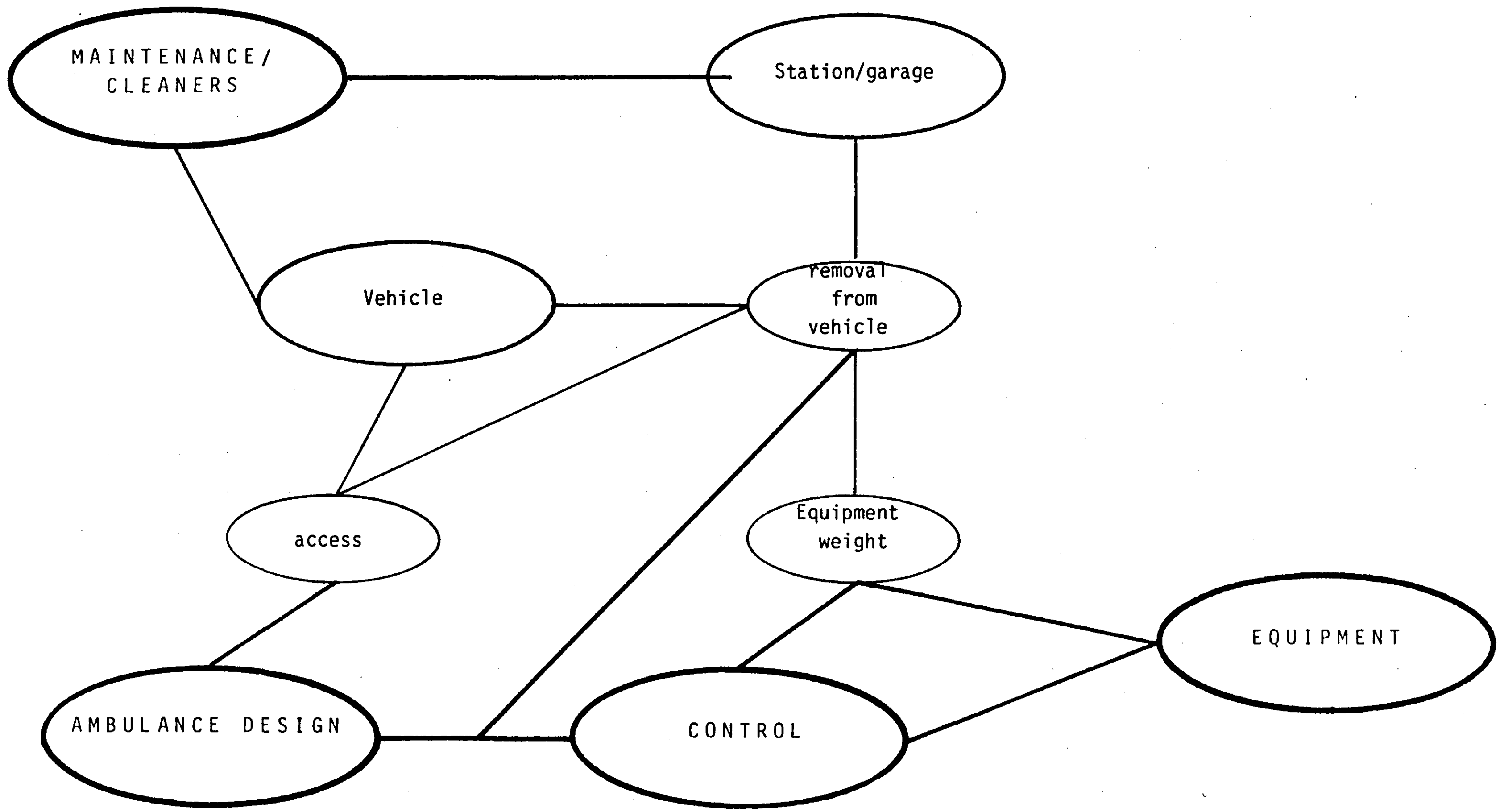
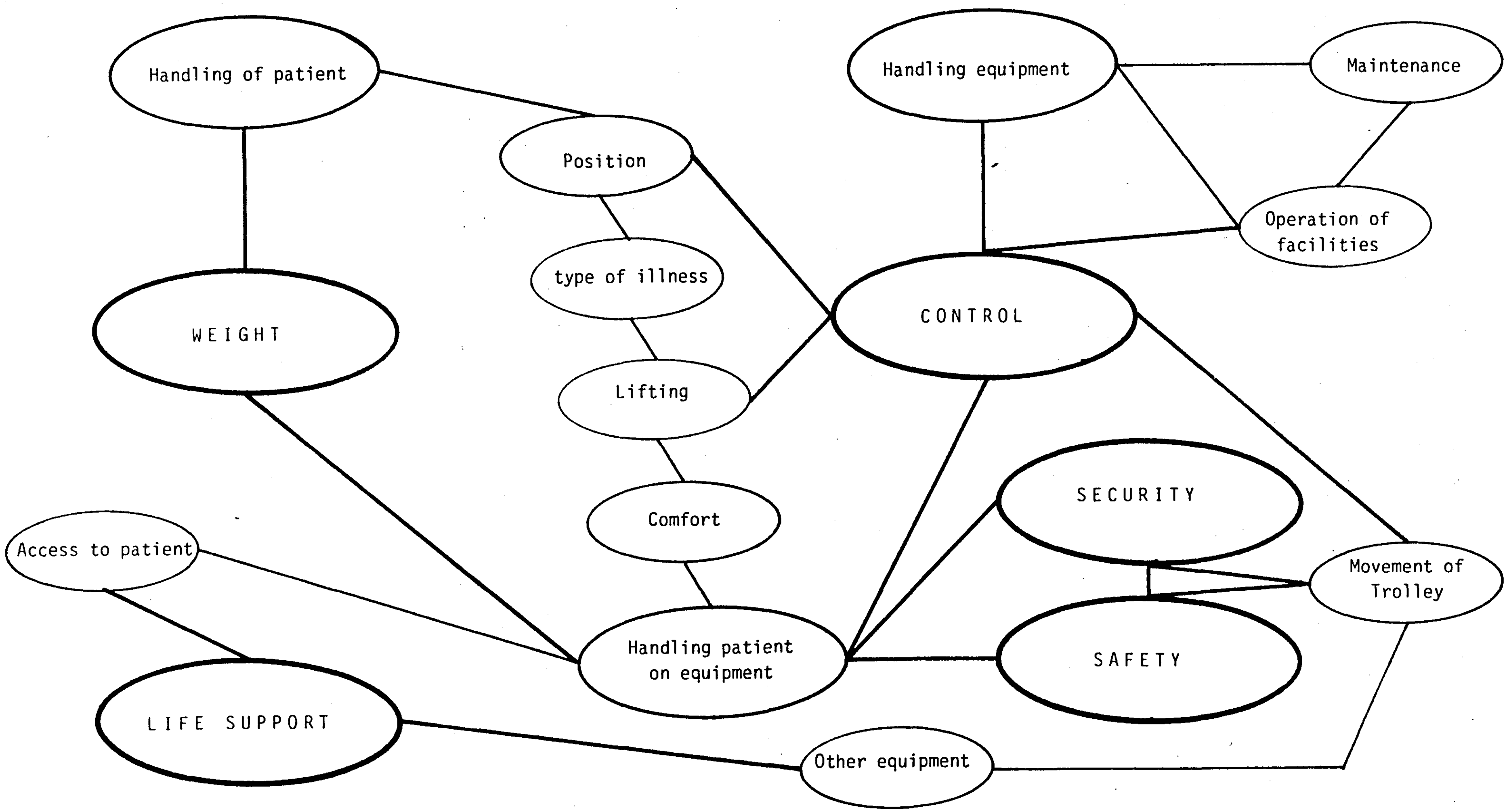


Fig. 45 - PRIORITIES



identified earlier. This enabled the major problems to be identified and related to the ergonomic framework derived from the analysis of the data collected on people, places and processes as shown in figs.41 - 45. This established that the problems could be grouped under the following main headings relating to :-

1) Patient handling
2) Equipment handling
3) Equipment control
4) Ambulance design

Areas 1, 2 & 3 form the basic structure for the development of the following performance specifications.

3.4 6. <u>Performance Specification</u>

3.4.1 This specification was developed from the ergonomic framework established and the problems identified in the research. It is divided into a general section giving overall recommendations and specific section dealing with certain areas in more detail. It is designed to be the framework against which the present design may be evaluated and a new design developed.

3.4.2 <u>GENERAL</u>

1. The trolley shall be capable of use as a bench type seat for up to four persons or as a bed for one reclining patient. (Appendix A)
2. It shall be capable of use in any ambulance. (Appendix A)
3. It shall be capable of use on either side of the ambulance or, if necessary, in the centre and facing in either direction. (Appendix A)
4. It shall not restrict access to the casualty during the ambulance journey.
5. It should be capable of use with other stretchers. e.g. The Scoop stretcher.

6. It shall provide the following patient positioning facilities:-
   1) Elevation of the trolley bed from bench seat height to hospital trolley height. (see 33 - 39)
   2) A means of maintaining the Trendelenberg or head downwards tilt. (see 48 - 50)
   3) A means of maintaining the Fowlers position or knee contour. (see 51 - 54)
   4) A backrest adjustable from 0° - 60°. (see 40 - 44)
   5) A means of maintaining an open airway and adequate support for cardiac massage. (see 45 - 47)
7. The trolley shall be capable of being propelled in the following ways:-
   1) Wheeling (see 23 - 26)
   2) Carrying and lifting (see 27 - 32) also (Appendix A)
8. The trolley should be capable of use without risk of injury to persons or damage to vehicles or buildings.
9. The trolley shall be capable of being quickly and easily restored to the 'ready for use' conditions after delivery of a patient.
10. The trolley shall be capable of being easily cleaned.

HANDLING

11. The total weight of the unladen trolley should not exceed the recommended limit of 25kg. (55lbs) (Appendix A)

SAFETY

12. The elevating mechanism shall be capable of being locked in both directions and in all positions.
13. The backrest locking feature shall provide a safety device that prevents accidental slipping.

14. The wheels shall be fitted with brake locks capable of operation regardless of wheel position and providing positive indication of the locked or unlocked mode.
15. The trolley shall provide a means of attaching patient retaining straps.
16. The trolley shall provide full stability when used in its elevated position under 'normal conditions'.
17. The trolley shall be capable of use with both loading/off-loading methods currently used by ambulance crews.
18. All controls and handles shall clearly indicate their function and be positioned where they are easily and safely operated.

SECURITY

19. The side rails shall provide adequate support to prevent the casualty rolling out under reasonable conditions, and a handhold should the casualty require one.
20. There should be no restrictions other than the recommended, to prevent the accommodation of larger patients.
22. The trolley should not contribute to the discomfort of the ambulance ride but should minimize this where possible.

CONTROL - moving trolley on ground surface

23. The trolley shall be capable of being wheeled on a reasonable floor surface without any danger to the patient.
24. The wheel diameter and width shall be such that the optimum ride conditions are obtained without impairing the turning action.
25. A means of towing the trolley in its lowest position shall be provided that enables the person towing to stand and walk in a comfortable manner.

26. The trolley shall be capable of being easily manoevred round corners such as are found in hospital corridors.

Lifting and carrying

27. It shall be possible to lift the trolley by both the side and end loading methods.
28. It shall be possible to carry the trolley using one person at each end and additional helpers on either side.
29. It shall be possible to maintain full control over the trolley and patient during the lifting and loading operations.
30. Any handles provided shall be reliable and of sufficient length to clear the casualty's head and feet when end loading.
31. The trolley shall be an appear to be reliable and strong when being lifted. (Maximum flexing allowed 25mm in length. B.S. 896)
32. There shall be no risk of injury to those persons carrying the trolley from any moving parts.

Elevation

33. The trolley shall be capable of elevation between bench height (500mm) and a height of 940mm with a maximum load of 127kg (20 stones) while on a smooth flat surface.
34. It shall be and appear to be stable when used in the elevated position.
35. It shall be capable of being wheeled in the elevated position with an average load on reasonable ground surface.
36. The locking mechanism shall provide variable height and be fitted with a safety device that will prevent any danger of the trolley bed slipping down during elevation.
37. The locking device shall be capable of operation from one end or from either side.

38. All handles or controls shall be accessible regardless of the trolley bed height.
39. The elevating mechanism should be capable of use in the ambulance as well as outside it.

<u>Backrest operation</u>

40. The backrest shall be capable of operation from either side both when in the ambulance and out of it.
41. The operating handle shall be situated where it is easily accessible when the backrest is horizontal and there shall be no risk of injury to hands or fingers during the lifting/lowering operation.
42. The operating mechanism shall provide a means of preventing the backrest from accidentally slipping down during use.
43. The locking mechanism shall have a positive action and provide a number of positions between 0° and 60° of elevation.
44. The base of the backrest shall provide adequate support for the performance of cardiac massage.

<u>Hyper-extension</u>

45. The hyper-extension facility shall be capable of quick and easy operation within a maximum time of 1 minute.
46. It shall provide a means of maintaining the head at such an angle that the airway is kept clear.
47. It shall be capable of operation in a moving ambulance.

<u>Trendelenberg position</u>

48. The Trendelenberg position shall provide a head down tilt of 12° to 15°.
49. It shall be capable of use both in the ambulance and out of it.
50. All handles and controls shall be situated where they are easily accessible regardless of trolley height.

Fowlers position

51. There shall be a means avaiable for maintaining a casualty with the knees supported in a bent position.
52. The mechanics for maintaining this position shall be capable of operation when the trolley is both in the ambulance and out of it.
53. It shall be possible to use this position without loss of dignity or embarrassment to the patient.
54. All handles and controls shall be situated where they are easily accessible regardless of trolley position.

Mattress

55. The mattress shall be capable of providing adequate but comfortable support for a reclining patient and a comfortable seat for sitting cases.
56. The mattress shall not add to the patient's discomfort by allowing sliding but the friction should not be such that a sliding transfer is made difficult.
57. The mattress shall be able to contour around all the positions provided by the trolley without difficulty.

Accessories

58. It shall be possible to use the following accessories with the trolley:-
    1) An infusion bottle or bottles
    2) Emergency oxygen or Entonox equipment
    3) A cardiac monitor and defibrillator
59. It shall be possible to maintain life support during the transfer between ambulance and hospital equipment.

3.5 Evaluation of the characteristics of the existing trolley

3.5.1 Before starting to formulate a new design for the trolley it was felt appropriate to review the existing one. The trolley used for this evaluation was a model 'Super 4' which offers the following facilities:-

1) Elevating mechanism
2) Backrest
3) Fowlers position
4) Trendelenberg position
5) C.P.R. facility

3.5.2 The evaluation was carried out against the performance specification (3.4) and can be summarised under the main headings used in the specification as follows:-

General

1. It can be used as a seat for 4 persons or a bed for one.
2. It will fit most ambulances though there are difficulties depending on ambulance design.
3. It can be used at either side or in the centre, again difficulties depend on the ambulance design.
4. The trolley itself does not restrict access to the casualty but in relationship with the ambulance, it does.
5. In theory it is possible to use other stretchers but in practice only the 'Scoop' stretcher can be used and not the Ferley type.
6. It provides the patient positioning facilities required but these are not always usable in the ambulance.
7. It can be wheeled, carried and lifted.
8. There is no risk of injury to persons and buildings when the trolley is being used but problems can arise with the use of the extended

side rail that can be used in a horizontal position and there is some risk of trapping fingers in the slides of the mechanism.

9. There are no problems in preparing the trolley for re-use.
10. It is not always easy to clean the elevating mechanism and the mattress.

Handling

11. The total weight of the trolley is 30Kg with an additional weight of 7Kg for the mattress.

Safety

12. There is some danger of the elevating mechanism slipping and it is difficult to operate in the Trendelenberg position.
13. There are no safety devices on the backrest other than the pin ratchet.
14. The wheel locks are difficult to operate, ineffective and do not provide any indication of locked- unlocked mode.
15. Patient retaining straps can be attached but there is no storage provided when not in use.
16. The trolley is reported to be stable but does not appear so when in use.
17. Both loading/unloading methods can be used but when side loading grease from the slides gets on the crews' hands.
18. There is no indication of the position or function of controls and operating handles, and some of them are not usable in the ambulance.

Security

19. The side rails are not high enough to provide adequate security and their use as a hand hold is lost when the padded rail is used.
20. The padded side rail does cause restriction and discomfort to the larger patient.

21. There are no problems of slipping with the extended contoured mattress but the C.P.R. mattress is slipping unless recovered.
22. The ride in the ambulance has been reported to be very uncomfortable but it is difficult to assess how much of this is due to the trolley design.

Control - moving trolley on ground surface

23. The trolley can be wheeled on any reasonable floor surface in its lowered position.
24. The wheels are not considered to give a satisfactory ride though manoeuvrability is good.
25. The towing handles are a source of continuous complaint as they break, bend and are too short or too long.
26. Manoeuvrability is good.

Lifting & carrying

27. Both loading methods can be used but the end loading method has a problem with stability while the side loading method has the problem of dust and grease from the slide.
28. Access for more than two persons to carry the trolley is good except for the grease as mentioned above.
29. Control of the trolley and patient is only possible with the side load method.
30. The carry handles are considered too short but their length is determined by the amount of flex when lifting the trolley.
31. The trolley flexes lengthwise when lifted giving the appearance of weakness though within the British STandard.
32. There is a risk of injury from the slides on the lower frame.

Elevation

33. The trolley is capable of elevation as recommended.

34. The trolley is stable but does not appear so with movement especially end to end.
35. It can be wheeled while elevated but this has been banned due to an accident.
36. The ratchet lock provides seven positions but there are no safety features and failure can occur.
37. The elevating mechanism can be operated from both side and end positions but the end handle becomes bent and it is not operable when the trolley is in the Trendelenberg position.
38. As stated above the operating handles cannot be used with the trolley in the Trendelenberg position.
39. These handles are not always accessible in the ambulance.

Backrest

40. When operating the backrest there is a danger of trapping hands especially when lowering it.
41. See 40.
42. There are no safety locks on the mechanism.
43. Five to seven positions are provided between horizontal and 60°
44. The sheeted base of the backrest is considered adequate support for cardiac massage.

Hyper-extension

45. This facility takes too long to operate.
46. It may provide adequate tilt to maintain an open airway.
47. Its operation in the ambulance is unknown as there are no reports of its use.

Trendelenberg position

48. This position provides a tilt of 10° to the horizontal.
49. It can be used outside but is very difficult to operate in the ambulance.

50. Access to the operating handles is difficult when the trolley is in its lowest position.

Fowlers position

51. This position is available.
52. It is possible to operate the mechanism for the position out of the ambulance but very difficult in it.
53. It does not cause any embarrassment to the casualty.
54. There is no access to the handles in the ambulance.

Mattress

55. The mattress is reported comfortable in most cases, though there were a few reports of discomfort.
56. The contour mattress is considered to provide adequate security from slipping but the C.P.R. mattress is slippery.
57. The ability of the mattress to contour round the positions is dictated by the foam thickness.

Accessories

58. Infusion stands and oxygen bottle holders are available but are not always present in the ambulance when needed and can cause handling problems. The cardiac monitor stand is not available.
59. Life support is only possible outside the ambulance by the use of the above equipment or additional staff aid.

3.5.3 The above evaluation shows that although the existing trolley performs all the required functions in theory, it is not always possible to use them in practice, particularly in the ambulance. This trolley has been in service for ten years and though it has improved handling and patient comfort there are areas where improvements can be made.

4 FIRST PROTOTYPE

4.1 New design - Introduction

4.1.1 From the evaluation of the existing trolley it became apparent that there were many areas where improvements would increase patient comfort and security and the trolley usability. The interface with the ambulance body today remains one of the major problem areas and although this cannot be completely solved with a new design of trolley it is possible to minimise the adverse effect by recognizing these restrictions and developing the new trolley to accommodate them. It would seem unlikely that a new ambulance body will be developed in the near future that will remove most of the present restrictions, but even if one were developed it would still be necessary for the trolley to be usable in an existing ambulance. It was decided, therefore, that it would be necessary to pay careful attention to the way in which various mechanisms are operated and to the position of the operating levers, as either one of these influences the other. This should increase the usability of the trolley enabling improved patient comfort and security and better handling qualities to be obtained.

4.1.2 When the existing range of trolleys culminating in the 'Super 4' model is examined it is possible to trace an evolutionary pattern that shows how additional features have been added to each version of the trolley in turn to create a new model.
This has resulted in many of the handling problems and the increased weight of the trolley today.
As the weight was considered a major problem it was felt important to achieve weight reduction without loss of strength. Attention should, therefore, be given to the integration of the different functions into a whole design and to the way in which

components were attached, as a reduction in the number of castings used would affect some weight saving. Similarly, it was felt that an examination of the structure of the trolley and the materials used might enable alternative solutions to be developed with equivalent strength but less overall weight. The structure would also be influenced by the decision to avoid sliding mechanisms either over or inside the main frame where possible. This would not only remove the risk of injury when handling the trolley but would also enable the use of an alternative section to be considered instead of the existing drawn tube.

4.1.3 While developing the new design it is necessary to be continually aware of the following:-

1) The manufacturing facilities available.
2) The handling techniques used with the trolley.
3) The position of the trolley in relation to other features in the ambulance.
4) The reasons for using the trolley.

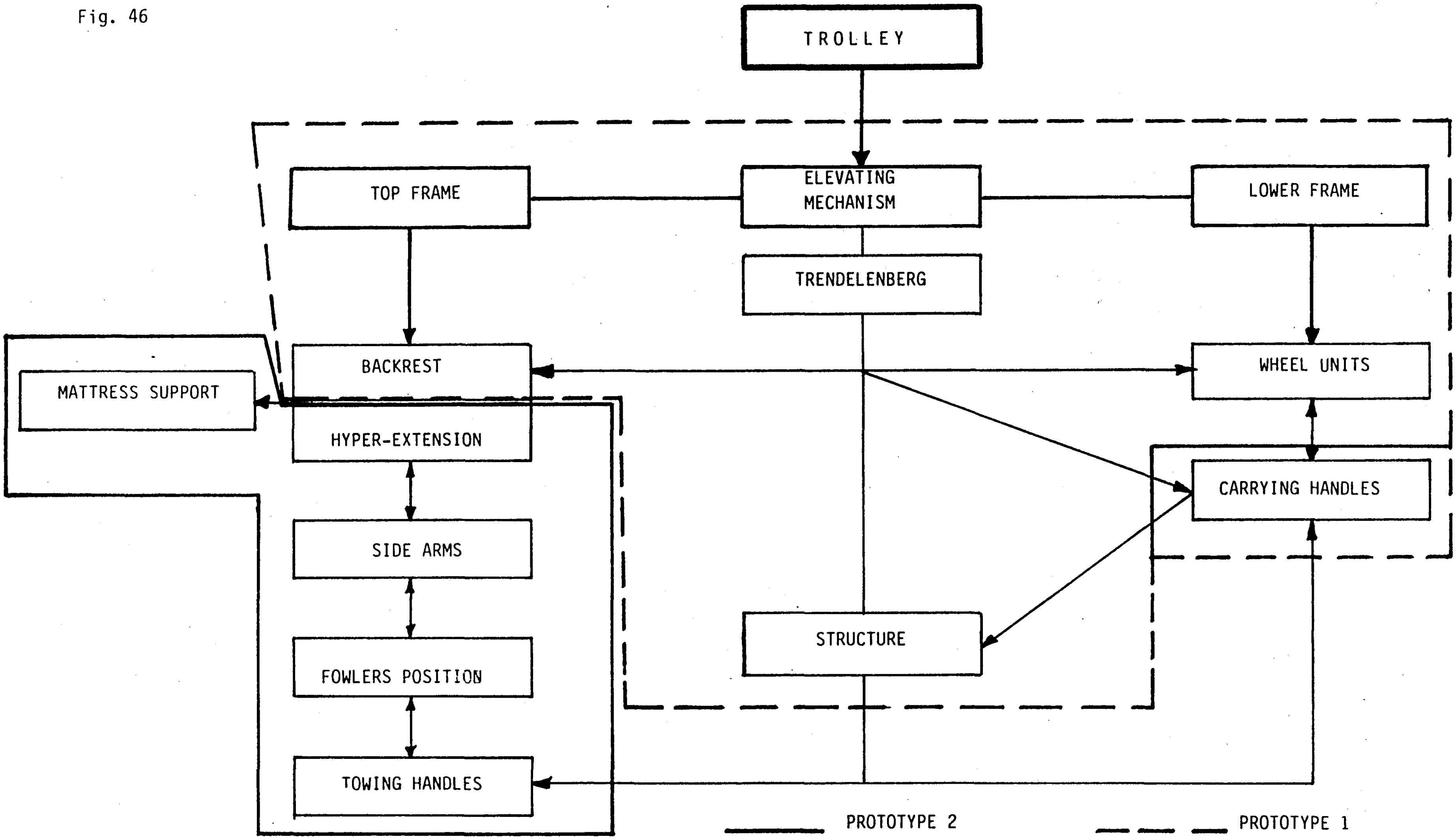
With these basic criteria as a framework upon which to build the new design the next stage was the development of a design strategy to plan how this should be done.

4.2 New Design - Development Strategy

4.2.1 The elevating stretcher trolley is a multi-function unit that enables it to be used as a couch for emergency aid and to accommodate a variety of injuries. However, because of the complexity of these functions which are all potentially inter-dependant it was felt appropriate to identify a system of design priorities which would enable each feature to be isolated when possible and a total design developed to ensure maximum efficiency. The design priorities would identify the very component around which the others would be developed and set the order in which this development should occur depending on the relationship of the components to each other. Once this has been established it is then possible to examine, if necessary, each component as a separate unit. For although it was recognised that the total design should be treated as a whole it may be necessary to compromise and treat some functions as individual mechanisms within the context of the total design as it was felt that this was the only way to handle such a complex device. This enabled a variety of mechanisms to be developed and evaluated within the total concept. It was, however, recognised that some mechanical efficiency may need to be sacrificed in order to achieve the best ergonomic solution within the whole design concept or alternatively, where a low ergonomic priority rating existed, compromise would be possible to allow maximum mechanical efficiency. A system of priorities was again used to evaluate the complex ergonomic requirements and preference was given to those that affected life maintaining or potentially dangerous situations. The ergonomic priority rating, however, does not necessarily coincide with the design priority rating and a component with a high design priority rating may have a low ergonomic rating or vice versa. Having established a structure for the development of the design using the priority system it became appropriate to discover the position of the individual components on this rating so that a complete plan for the design development could be formulated.

4.2.2 To determine the order of priority the structure of the trolley was examined and it was decided that in order to fulfil the requirements of the specification the structure would need to consist of 3 main sections:-

Fig. 46


TROLLEY
TOP FRAME
ELEVATING MECHANISM
LOWER FRAME
TRENDELENBERG
BACKREST
WHEEL UNITS
MATTRESS SUPPORT
HYPER-EXTENSION
CARRYING HANDLES
SIDE ARMS
STRUCTURE
FOWLERS POSITION
TOWING HANDLES
PROTOTYPE 2
PROTOTYPE 1

1) The upper section carrying the majority of the multi-postural features and forming the bed.
2) The lower section comprising the framework carrying the wheel units and forming the base upon which the upper section rests.
3) The elevating mechanism which enables the top section to be raised a certain height above the lower section and maintained there.

The elevating mechanism was seen, therefore, as the main design priority as it forms part of the supporting structure for the trolley bed and as it is a dominant feature whose nature of operation would exert the greatest influence over the other functions. Consideration was also given to the fact that this feature caused the most serious problems in the existing trolley and careful attention would need to be given to the design to overcome these difficulties.

4.2.3 Having established the major design component a plan was drawn up for the development of the other functions either individually or as groups depending on their structure and interdependance. This plan is given in fig. 46. Although the plan shows the development of the functions in sequence, the actual design process involved the development of ideas for design solution for all the major functions simultaneously. This enabled the development of the whole design to be monitored and controlled. However, emphasis was placed on the initial development of the elevating mechanism.

4.2.4 While considering the elevating mechanism it was decided that it should be possible to combine it with the Trendelenberg position as it appeared that both required similar operations. Each one requires a lifting action although with the elevating mechanism this is a parallel but vertical lift whereas the Trendelenberg position requires the foot end of the trolley lifted about the pivot at the head end, so that the feet are elevated. The design and development of these features occupied a major portion of the time allocated to the first stage of the development leading up to Prototype 1.

4.2.5 The backrest was considered to be the second priority as this is one of the most used functions on the trolley and can have a severe detrimental effect ona patient should failure occur. In the existing trolley the hyper-extension position is combined with the backrest and considered as part of it as this position involves the support of the neck and chest. However, it was decided to re-examine this principle and develop the backrest accordingly as the hyper-extension mechanism would have a direct effect on the method by which the backrest would be operated. The backrest was also developed during the first prototype stage.

4.2.6 As Prototype 1 was intended as a framework for the attachment of mock-ups of the functions so that the viability of certain ideas could be tested as they were developed and also to allow an ergonomic assessment to be made when handling the trolley, it was necessary to determine at an early stage the basic material form and the structure of the framework. This was only possible after the basic design concept for the trolley had been established as this would influence the material used. However, once established the top and lower frames could be designed and built enabling Prototype 1 to start taking a 3-dimensional form on which ideas can be tried and assessed.

4.2.7 Other features would also be developed to prototype or mock-up stage during this first development phase. The wheel units would be developed to prototype stage as they form an integral part of the lower frame and are required for the assembly of the structure. Mock-ups of the carry handle would allow ideas to be assessed for positioning in relation to load and storage during handling. The side arms were also developed to mock-up stage to test the usability of the idea and their positioning relative to the other features on the trolley. At this point it was decided that Prototype 1 should be sufficiently advanced to allow assessment of the functions shown so that any change required could be incorporated into Prototype 2.

4.2.8 It was planned that Prototype 2 should be developed from Prototype 1 and incorporate the re-designed features as necessary from the assessment of the first prototype. Then once the final design of the basic mechanisms was developed it would be possible to finalise the mechanisms for the other functions relating them as necessary to the whole design concept. Prototype 2 would be used, therefore, to detail the concepts used in Prototype 1 and to develop the remaining features in relation to each other and to the elevating mechanism and backrest within the whole designed unit.

4.2.9 It was planned that Prototype 2 should show the total design concept and enable a handling evaluation exercise to be completed similar to the exercise arranged during the research (para. 3.2.5) in order that a comparison could be made between the new design and the existing trolley. This would then enable suggestions to be made concerning the further development of the trolley.

4.3 The Elevating Mechanism Development

4.3.1 The elevating mechanism as stated above was seen as the major component in the trolley unit around which the remaining components would be designed. The existing system uses a scissor mechanism but as this had acquired the reputation of being unsafe it was decided to examine other means of achieving the required height with parallel lift. It also seemed possible, because of the nature of the two functions, to link the Trendelenberg position to the elevating mechanism so combining the two separate mechanisms into one system, saving weight and improving the handling. The new design, therefore, aims to achieve the following:-

1) Increased safety
2) Improved handling
3) Weight reduction

4.3.2 Initially a number of ideas were generated which were then assessed for viability. Some of these were then selected to be developed further in order that their workability could be assessed. There were two methods of determining the workability and structure of these ideas. The first method involved the numerical evaluation of the system using the number synthesis theory. This enables the number of links in a mechanism and their connections for optimum performance to be determined. When a mechanism consists of a number of links connected together by a number of joints then the system has a certain degree of movement dependant on the formation and relationship between the links and joints. This movement is called the degree of freedom and where this equals zero the mechanism cannot move and becomes a structure. Most mechanisms require one degree of freedom which allows movement to be controlled in one direction only. The mobility of a mechanism can be calculated by using a numerical equation called "Grübler's Criterion" which states that

$$F = 3n - 2_{j1} - {}_{j2} - 3 \quad (21)$$

where F = the mobility of the mechanism

n = the number of links

j_1 = the number of joints with 1 degree of freedom. eg. hinge, slides.

j_2 = the number of joints with 2 degrees of freedom. eg. screw.

By applying this to the proposed ideas it was possible to determine their mobility and the relationship between the links and joints. The second method involved building pin-jointed card-board medels of the mechanism to test the number synthesis results and to allow the form of the mechanism to be assessed.

4.3.3 It was decided that the mechanism required to elevate the trolley needed a mobility of one degree of freedon when operational and 0 degrees of freedom when static. With the establishment of this criteria it became possible to examine the ideas generated initially and assess their workability as shown in fig. 47. It can be seen from these that only five give the required 1 degree of freedom of which three are variations on the scissor mechanism. As this is in use on the existing trolley it was felt it had been well tested and the remaining two mechanisms should be examined in more detail. Mechanism No.8 was developed to pin-jointed cardboard model stage but was discarded as being too complicated. This left the last mechanism which seemed to offer the simplest and most effective solution.

4.3.4 It consists of a double parallel motion at one end and a single unit at the other tied together across the centre joints by a sliding member that allows the lift to be parallel and vertical with no end movement. It will also fold into a small space and appeared to offer the possibility of combined Trendelenberg position by adjustment of the distance between the parallel legs. As shown by the calculations, when free this mechanism has a mobility of 1 degree of freedom and movement is achieved by effecting a slide between links (9) and (19). When this slide is locked, links (9) and (10) become one and the mobility is 0. To

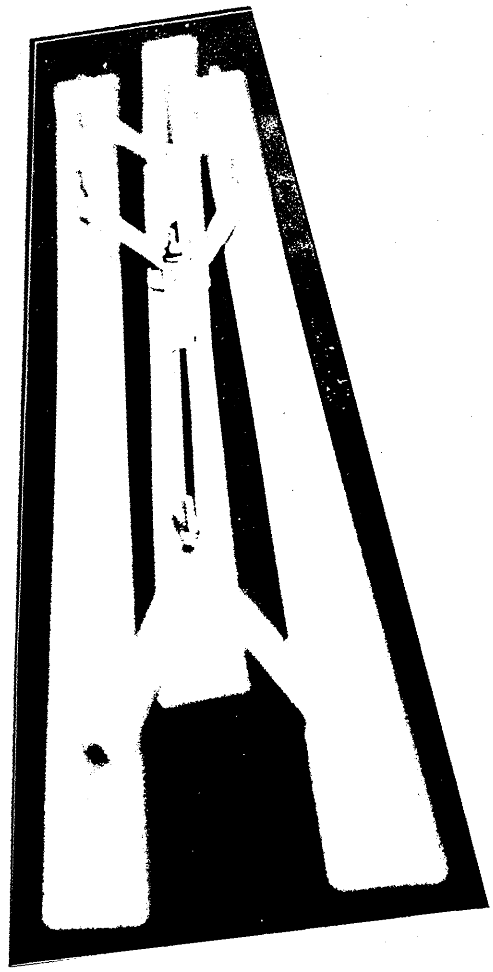


Fig. 48

An early working model demonstrating the elevating mechanism - closed.

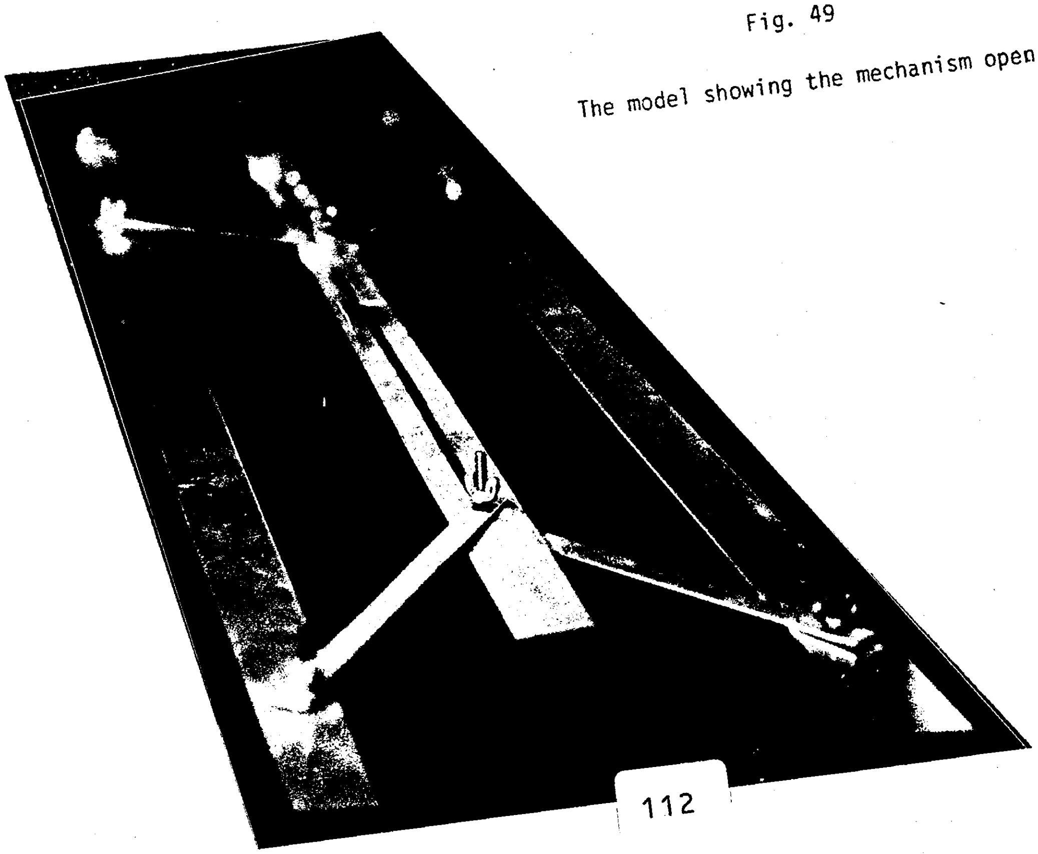


Fig. 49

The model showing the mechanism open.

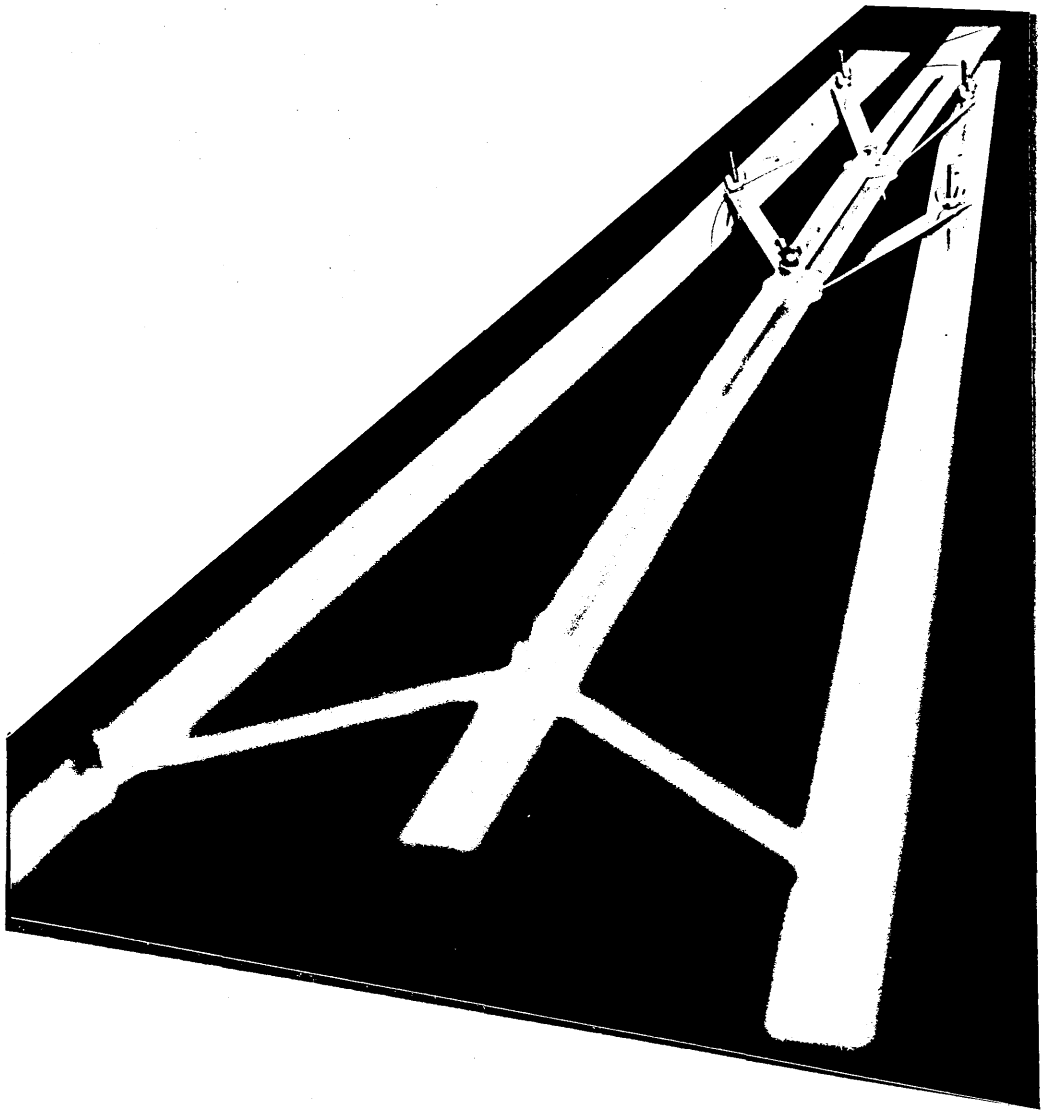


Fig. 50

The same model demonstrating the Trendelenberg position by altering the distance between the parallel legs.

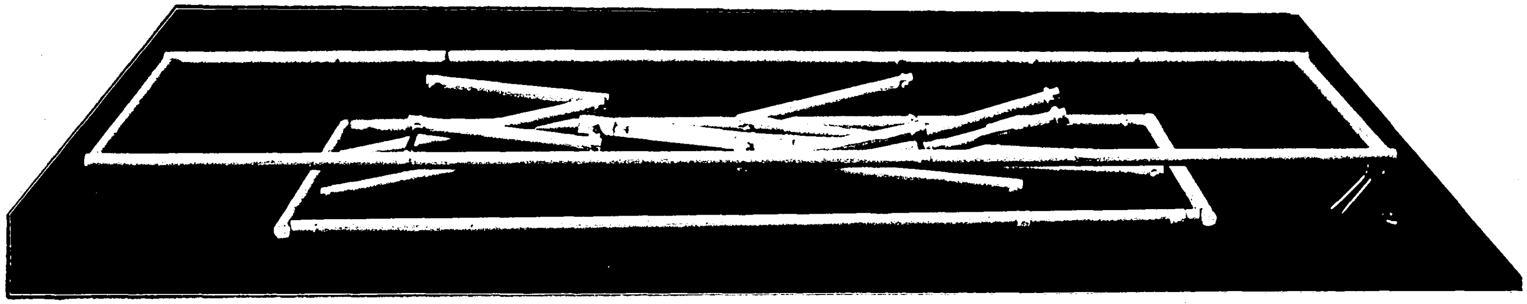


Fig. 51

A model of the trolley with the elevating mechanism using round section material - lowered

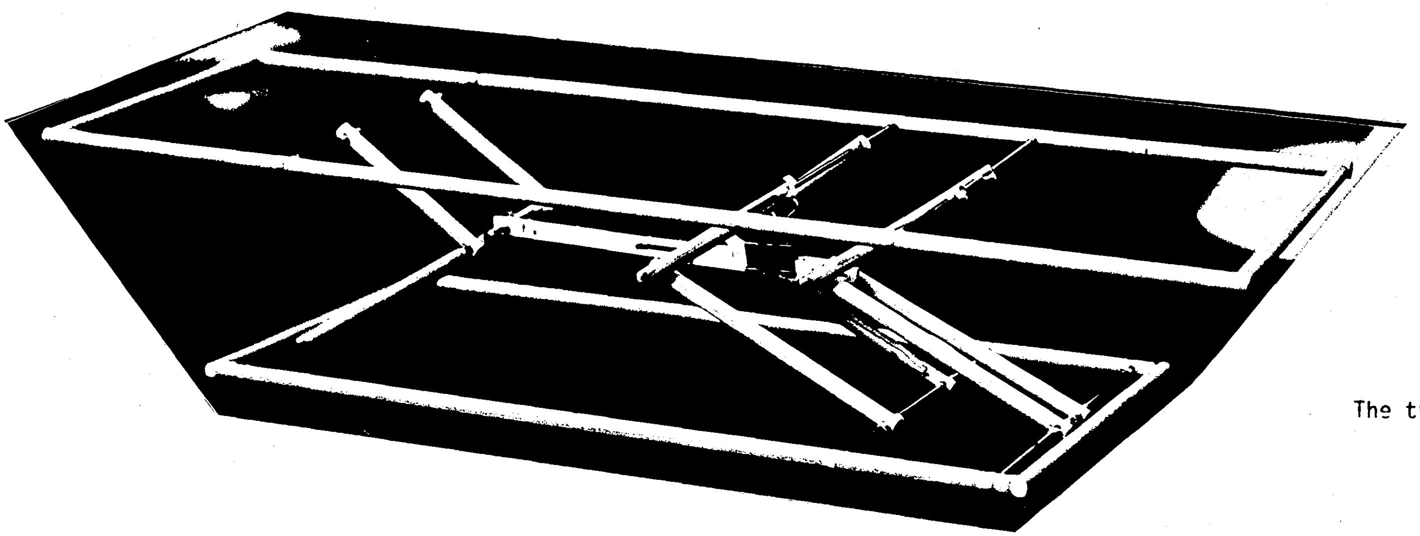


Fig. 52

The trolley bed raised.

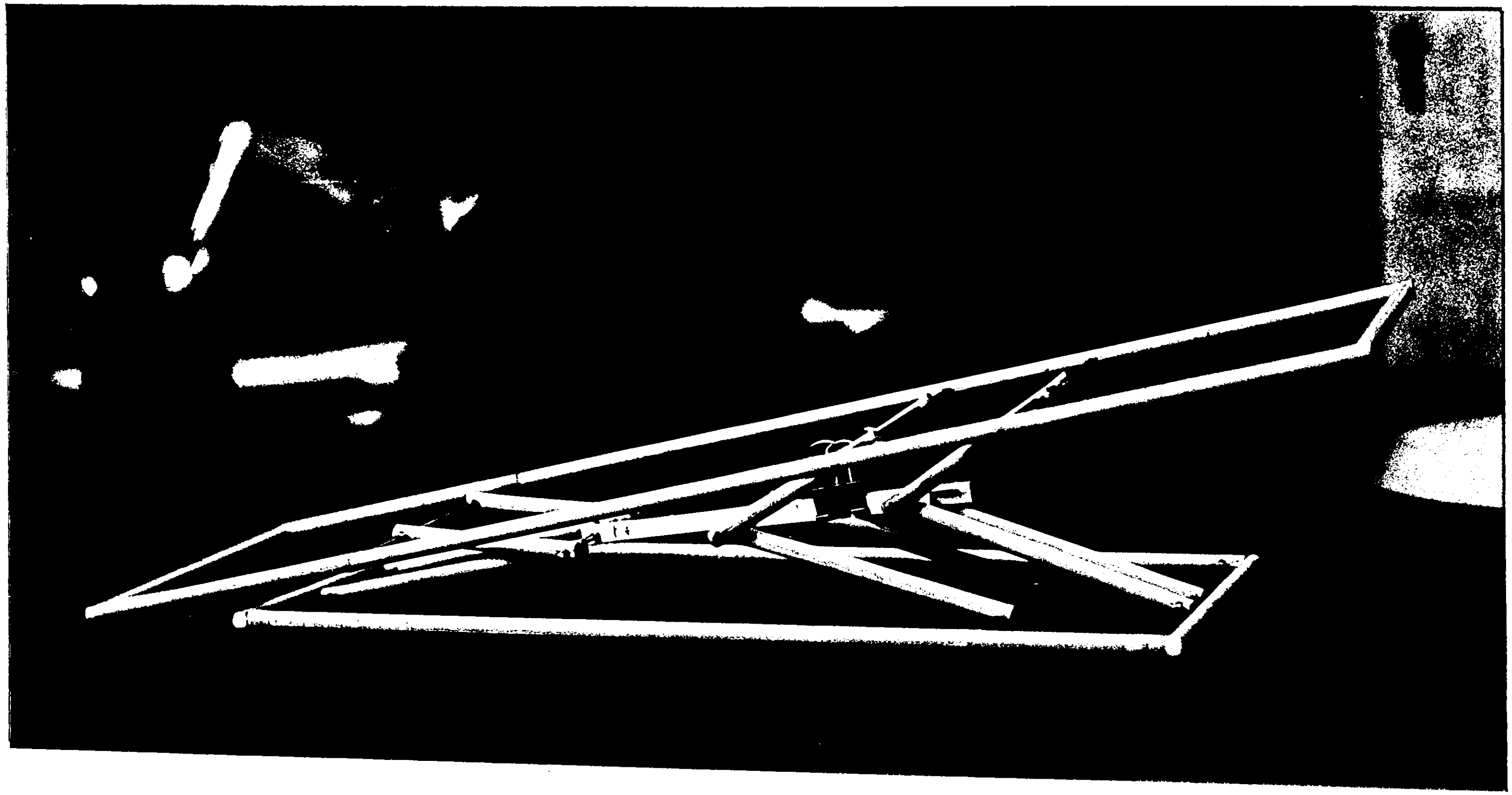


Fig. 53

The Trendelenberg position.

test this mobility a pin-jointed cardboard model was made enabling the structure and jointing to be assessed. As this proved satisfactory the next stage developed the mechanism further by use of scaled working models. Figs. 48, 49 and 50 show a model of the basic structure of the mechanism that was used to develop the sliding mechanism, length of the legs to give the required height and the distance the centre slide would need to move to achieve this. It also enabled the Trendelenberg combination to be explored as shown in fig.50. Two models were then built to show the shape and form of the trolley structure utilizing the two different material sections in order to evaluate the appearance of the trolley. Figs. 51, 52 and 53 show the use of tubular section material and figs. 54 and 55 show the appearance of a rectangular section. However, in examining these sections it was necessary to consider the benefits and disadvantages of each as well as their appearance. Tubular material had the advantage that it is currently in use for the existing stretcher trolleys therefore there would be material, castings and components available, however, unless the new design utilized the existing castings which would be restrictive then new fastening components would need to be made. The rectangular section material in the model represented a flat-oval section which has the advantage that the flat sides afford a surface to which other components can be more easily fastened. However, this shape requires special castings and tooling where components fit into or around the section. It was felt, however, that the advantages outweighed the disadvantages particularly as calculations shown below demonstrated that the flat-oval section has a greater strength to weight ratio in the required direction than the tubular section and as its appearance was more suited to the chosen

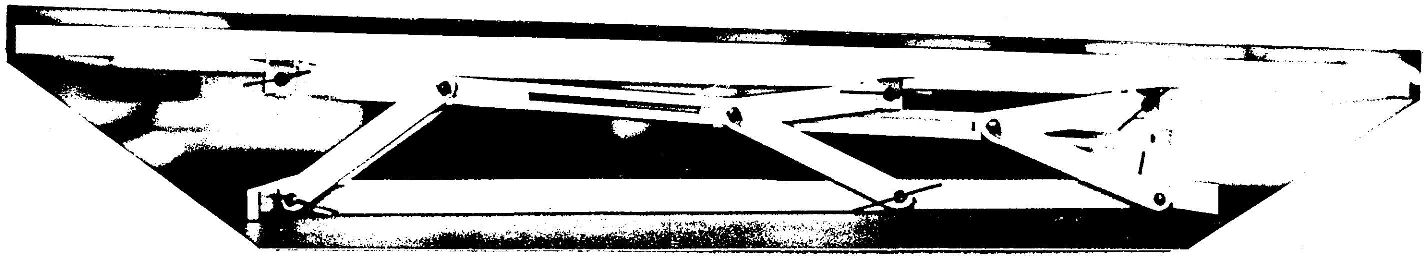


Fig. 54

A model of the trolley demonstrating the appearance of rectangular section materials - side view.

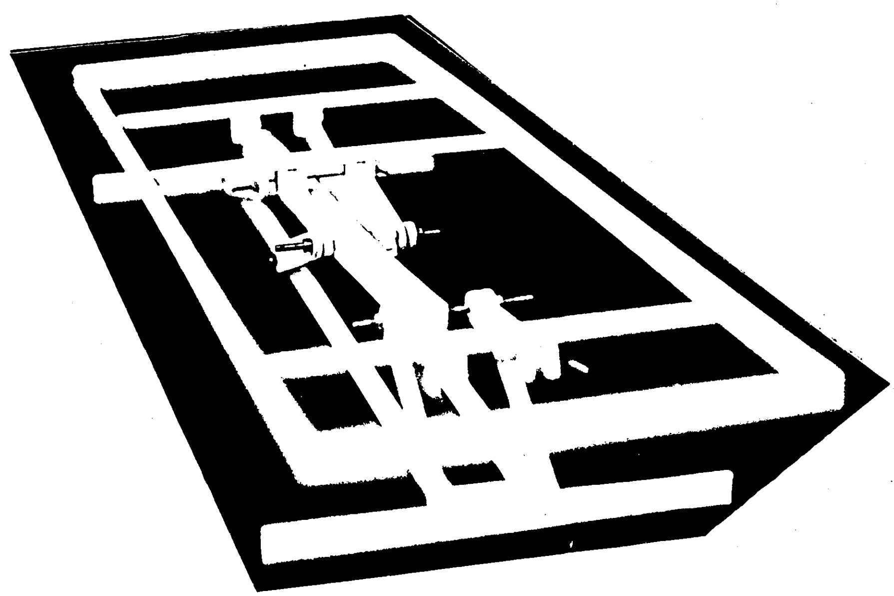


Fig. 55

View from one end.

mechanism it was decided to use this section for the trolley design.

Tube used for the existing trolley frame:-

Diameter 27.78mm
Wall thickness 2.34mm

Using I = second moment of area
D = external diameter
d = internal diameter

Then $I = \frac{\pi (D^4 - d^4)}{64}$

$= \frac{\pi(27.78^4 - 23.1^4)}{64}$

$= 15.258 \times 10^3 mm^4$

Weight = .506Kg/m

For new design using rectangular section
41.9mm x 19.05mm with .91mm wall thickness

Where I = second moment of area
b = breadth
d = depth

$I = \frac{bd^3}{72}$

$= \frac{19.05 \times 41.91^3}{12} = 24.345 \times 10^3 mm^4$

Weight = .281Kg/m

The rectangular section has a higher 'I' value and weighs less per metre length than the tube.

Difference in weight/m = .225Kg/m

Fig. 56

The working model of the elevating mechanism demonstrating the closed position.

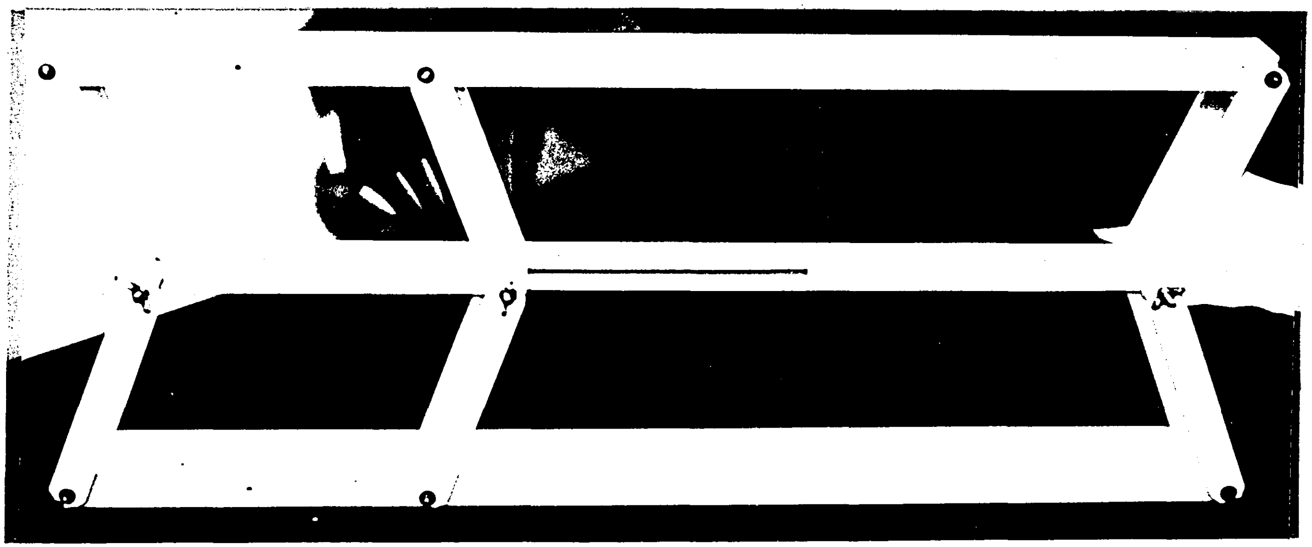
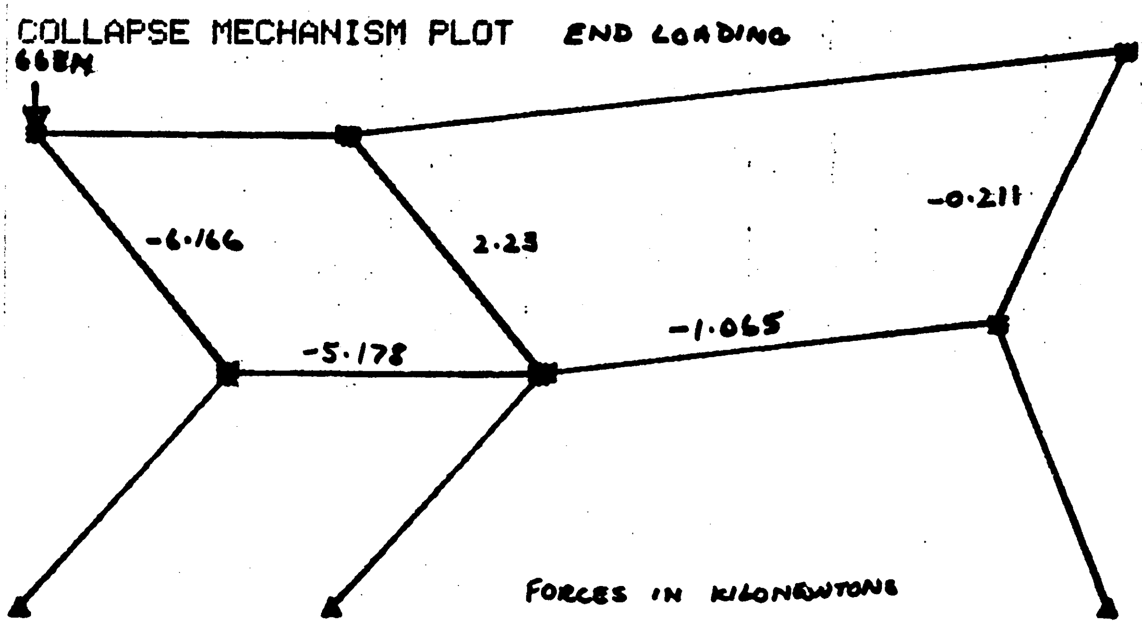


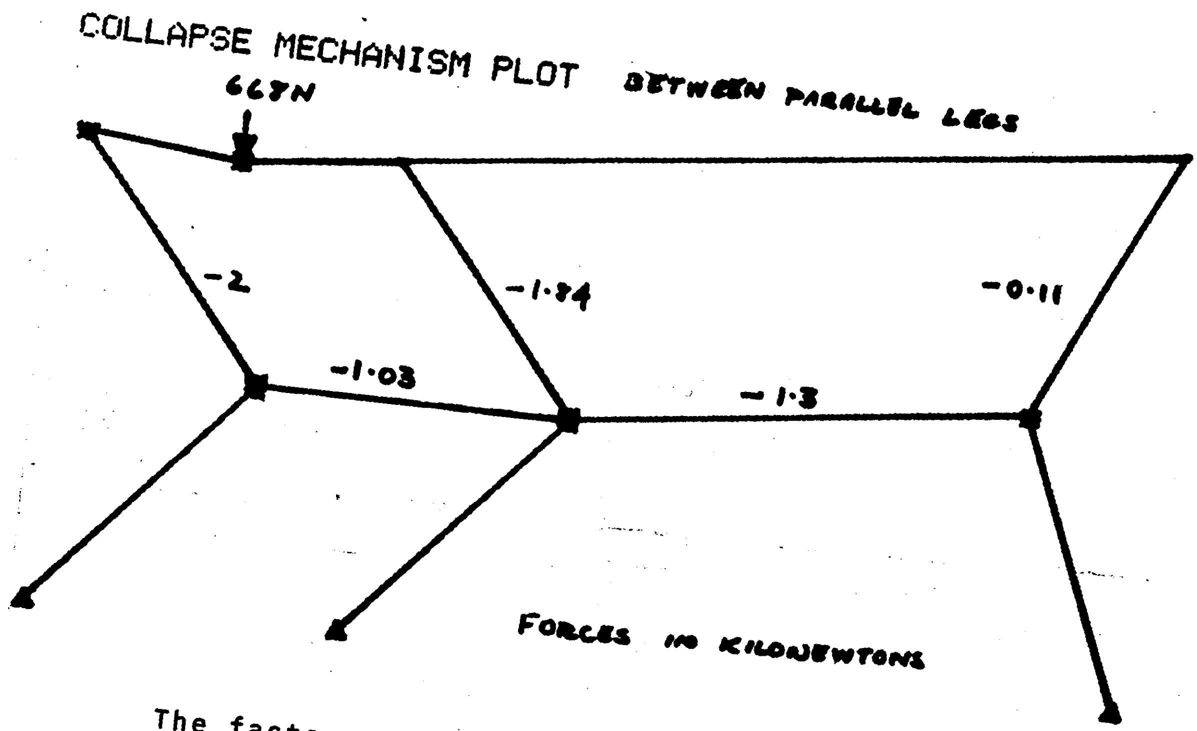
Fig. 57

The elevated position.

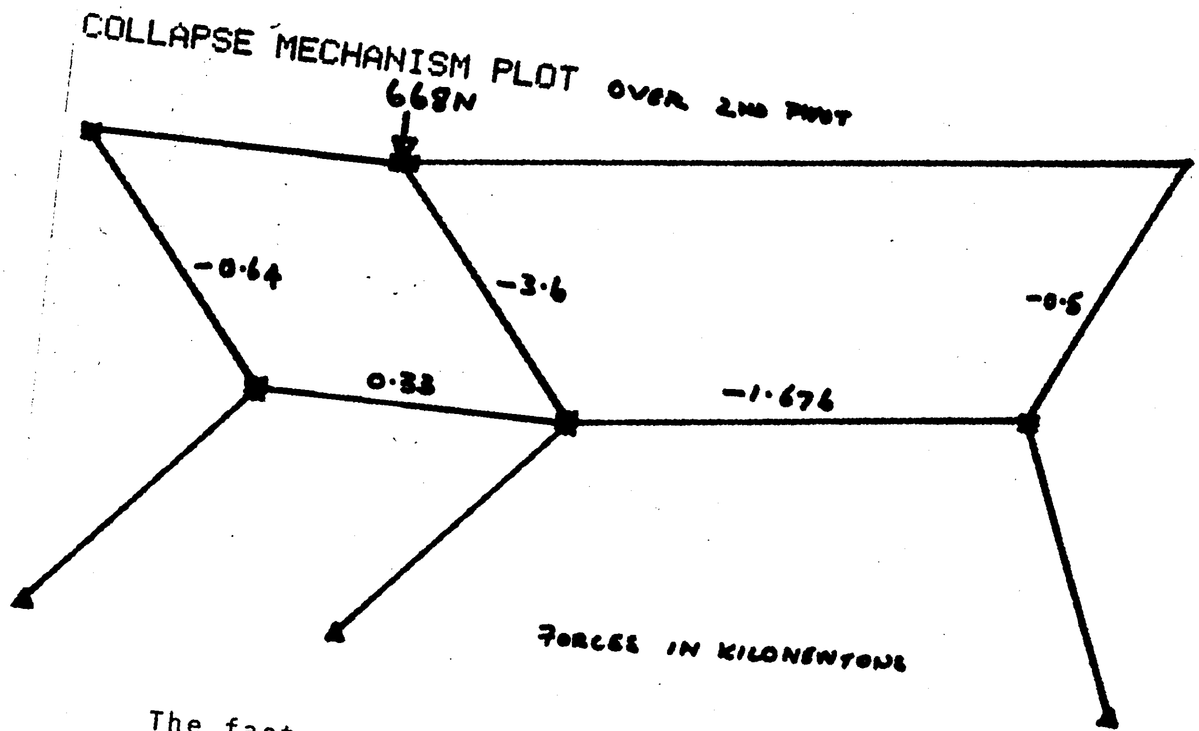
4.3.5 Once the section shape and material to be used had been decided it became necessary to examine the ways of providing the control slide and locking mechanism. A scale working model was built as shown in figs. 56 & 57 which demonstrated that this centre unit would be an area carrying a considerable stress and, since the structure is statically indeterminate it was decided to analyse this by computer methods. A software package PCAP, available at Sheffield City Polytechnic was used to analyse the effects of a 300lb person positioned at five critical locations. Load applied is halved since only one side is analysed i.e. 668 Newtons. This programme gives graphical output of the mode of collapse, factor of safety and also data concerning the forces acting in the members. This information has been transferred to the graphical output for each load condition as shown below.



The factor of safety = 7.2

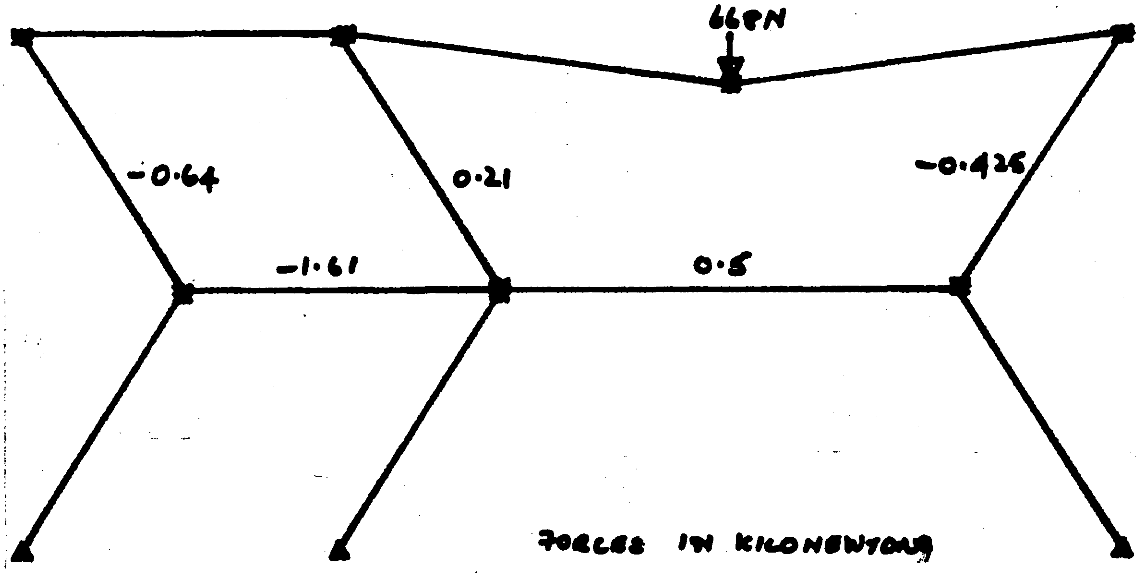


The factor of safety = 6.06



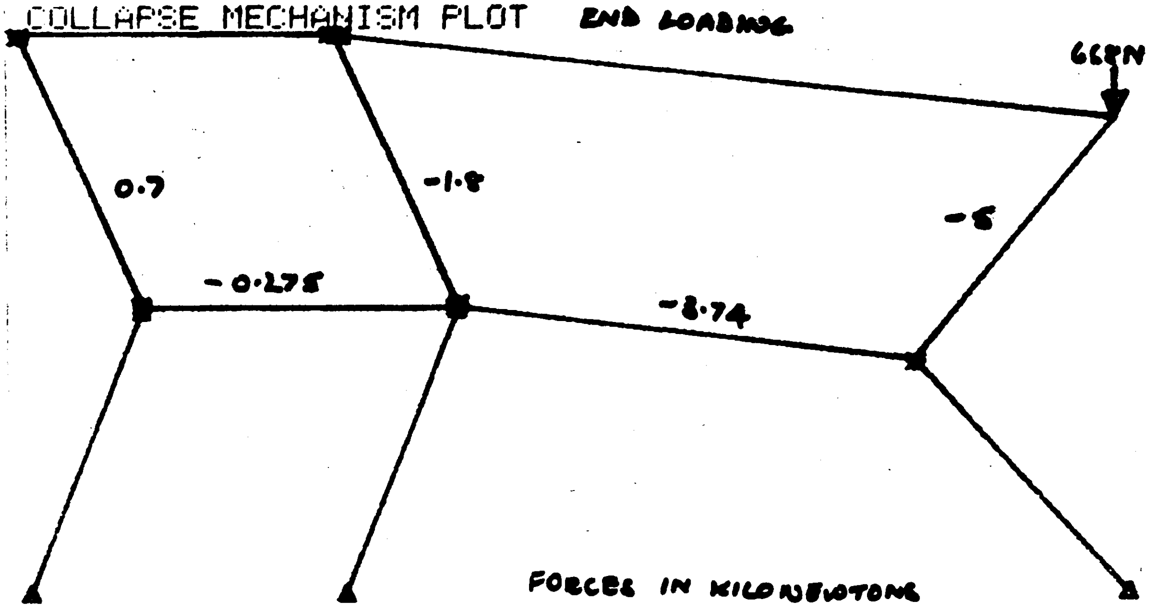
The factor of safety = 7.07

COLLAPSE MECHANISM PLOT CENTRE NON PARALLEL LEGS



The factor of safety = 2.8

COLLAPSE MECHANISM PLOT END LOADING



The factor of safety = 7.07

From these results the maximum load in each of the support legs and middle struts has been identified as follows:-

For middle strut L.H. - -5.2 KN
R.H. - -3.74 KN

L.H. leg - -6.16 KN
Middle leg - -3.6 KN
R.H. Leg - -5 KN

Support legs will fail under compression or buckling.

1) compression:- stress $= \frac{\text{load}}{\text{area}} = \frac{6.160}{110} = 56 N/mm^2$

well below aluminium yield stress of $185/mm^2$

2) buckling:- using $P = \frac{\pi^2 EI}{l^2}$ where $l = 390mm$
$E = 69 \times 10^9 N/m^2$

I value for oval section = $24.5mm^4$

$$P = \frac{\pi^2 . 69 \times 10^9 \times 24.5 \times 10^{-9}}{.395^2}$$

$$= 34 \text{ KN}$$

The following calculations for the centre strut include the piston size for a hydraulic cylinder to drive the centre mechanism as discussed on page 128.

1) Piston size for cylinder for hydraulic circuit.

If force in centre unit = 5200N

Let P = 5200N

To decide on diamter of rod using

$$P = \frac{\pi^2 EI}{L^2} \quad \text{for pin jointed strut}$$

where L = 955.52mm

for steel $E = 200 \times 10^9 N|m^2$

I = second moment of area

$$I = \frac{PL^2}{\pi^2 E} = \frac{5200 \times (0.95552)^2}{\pi^2 \times 200 \times 10^9}$$

$$= 24.06 \times 10^{-10}$$

For circular section $I = \frac{\pi D4}{64}$ $\therefore D^4 = \frac{I64}{\pi}$

where D = diameter

$$\therefore D^4 = \frac{24.06 \times 10^{-10} \times 64}{\pi}$$

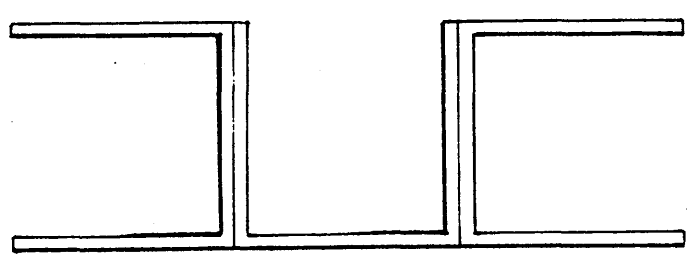
$$\therefore D = 1.49 \times 10^{-2}$$

$$= 14.9\text{mm}$$

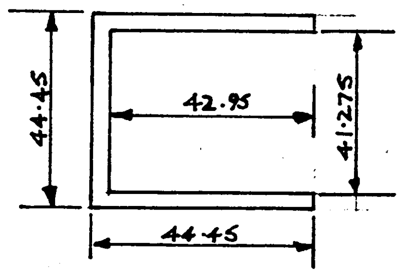
The minimum dimension of rod needed = 15mm

2) As the hydraulic system did not work the following structure was evaluated for the centre bar, using aluminium channel.

44.45mm square and 1.5875mm wall thickness.



For rectangular section $I = \frac{BD^3}{12}$



$$\therefore I = \frac{(BD^3)}{12} - \frac{(bd^3)}{12}$$

$$= \frac{44.45^4}{12} - \frac{42.95 \times 41.275^3}{12}$$

$$= 7.364 \times 10^{-8} m^4$$

Using $P = \frac{\pi^2 EI}{l^2}$ where $l = 973mm$

E for Aluminium = $69 \times 10^9 N|m^2$

$$P = \frac{\pi^2 \times 69 \times 10^9 \times 7.364 \times 10^{-8}}{0.973^2}$$

$$= 52.97 \times 10^3 N$$

This is greater than the force in the system therefore it can be used.

Many ideas were again explored and some were then selected for further examination. The nature of the mechanism reduced the number of possible workable solutions as the criteria for the elevating system require that it should be capable of elevating through 500mm yet fold down into 150mm including the operating mechanism and lock. This precluded the use of any form of vertical lift

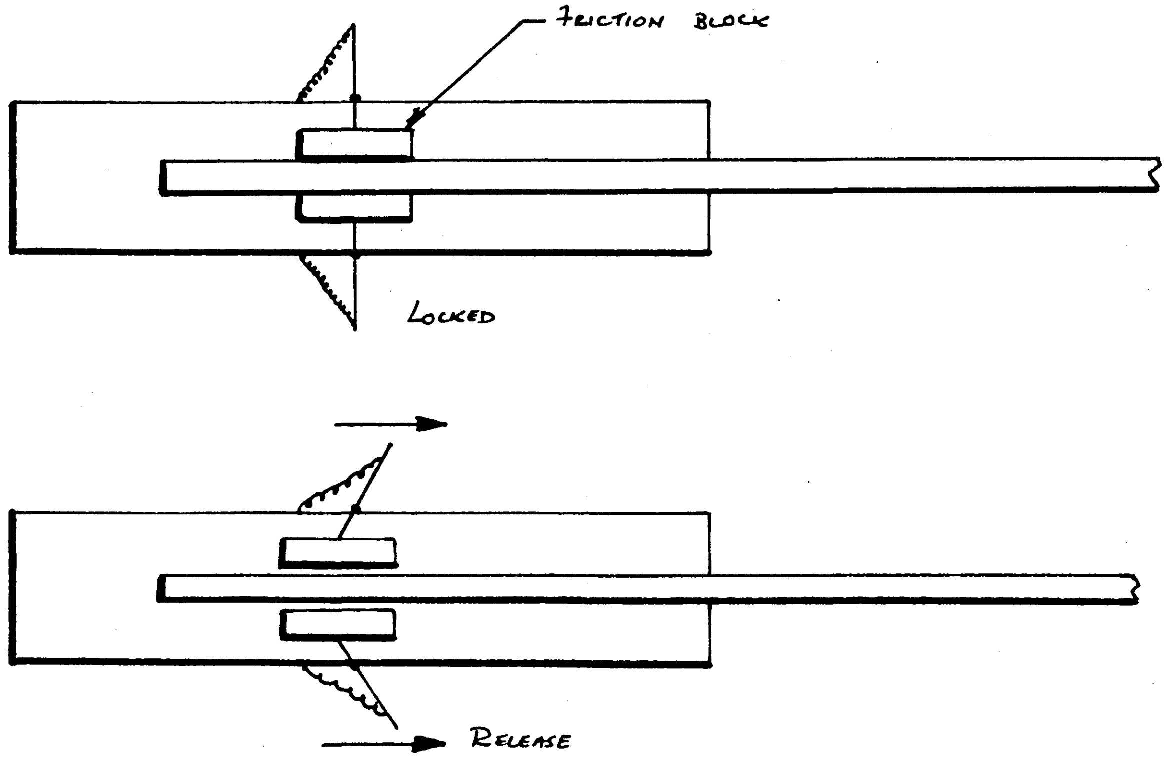


Fig. 58

A Friction lock system 1.

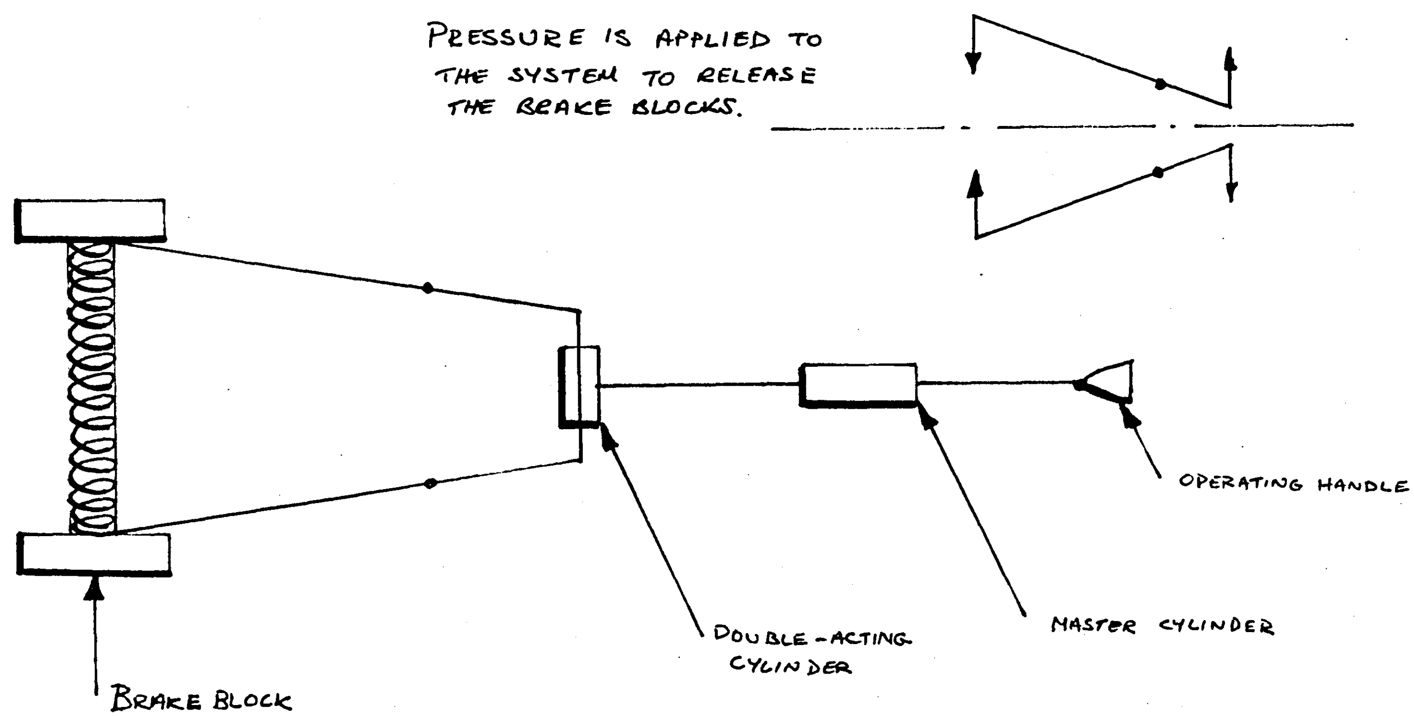


Fig. 59

A Friction lock system 2.

mechanism and left as the only workable solution some form of horizontal slide in the centre of the unit.

4.3.6 While examining and assessing the most likely methods of elevating the trolley, the possibility of linking the Trendelenberg position operating mechanism into the elevating mechanism was explored. The elevating mechanism chosen seemed to provide a good system for this dual purpose and exploration with the models enabled both Trendelenberg and anti-Trendelenberg positions to be attained by adjusting the distance between the parallel links at the centre in one or the other direction.

4.3.7 In the meantime different methods of locking the centre slide unit were examined and tried. The most obvious method was to use a ratchet system but this has the disadvantage of some degree of noise during use and of limiting movement to a series of positions. It was felt also that there would be prejudice against a ratchet system because of the problems encountered with the existing design, and it would be difficult to meet the requirements of the specification which determines that any locking mechanism controlling the elevation and descent of the trolley bed should contain some form of safety device to prevent the bed from falling in the event of mechanism failure. This resulted in the development of friction devices shown in figs. 58 & 59 but these were rejected as being inadequate after scale mock-up trials. These locking systems were all based on mechanical devices but another method investigated the use of a hydraulic circuit to control the elevating mechanism. The use of hydraulics also provided the opportunity to investigate the possibility of providing either assistance to the manual lift required to elevate the trolley or the full lifting power. A circuit diagram for assisting the

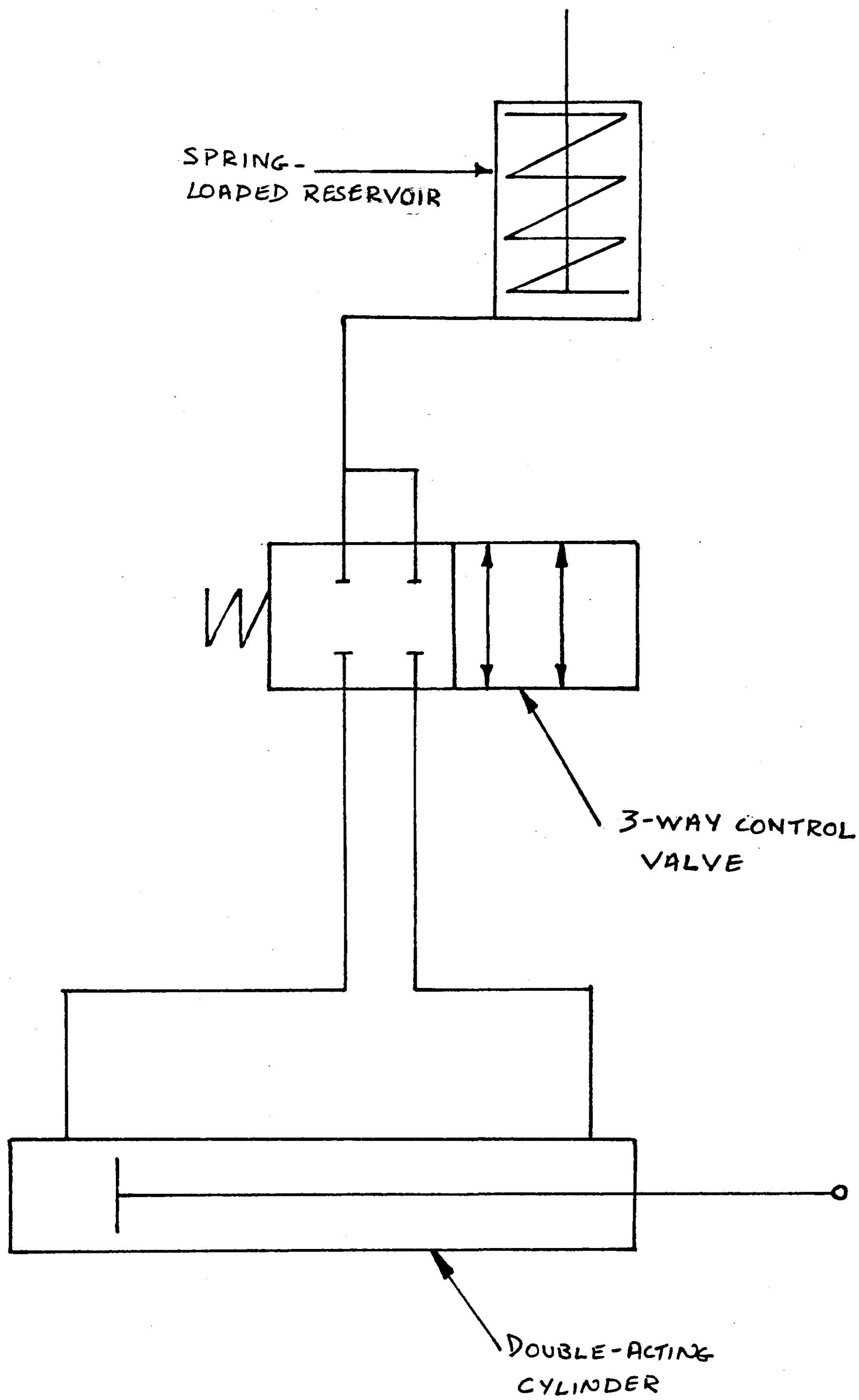
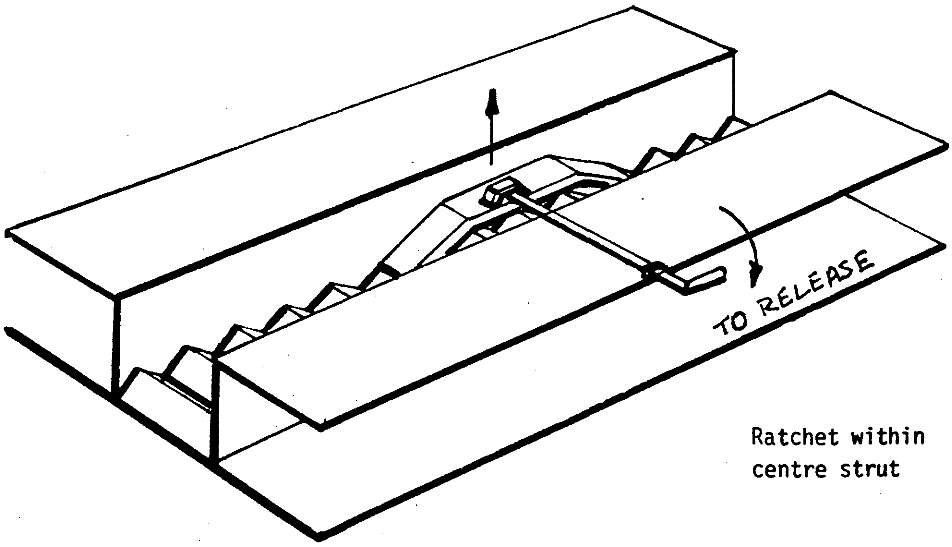
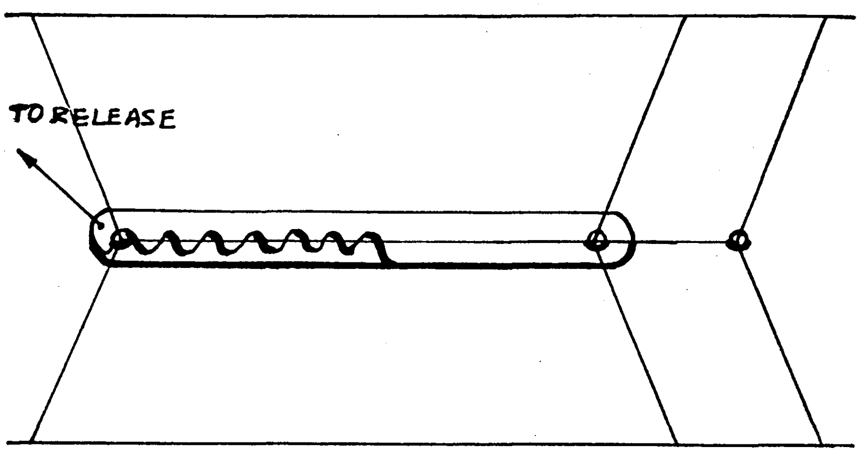


Fig. 60

Hydraulic circuit



Ratchet within
centre strut



Ratchet bar forms part of centre strut

Fig. 61
Ratchet mechanisms

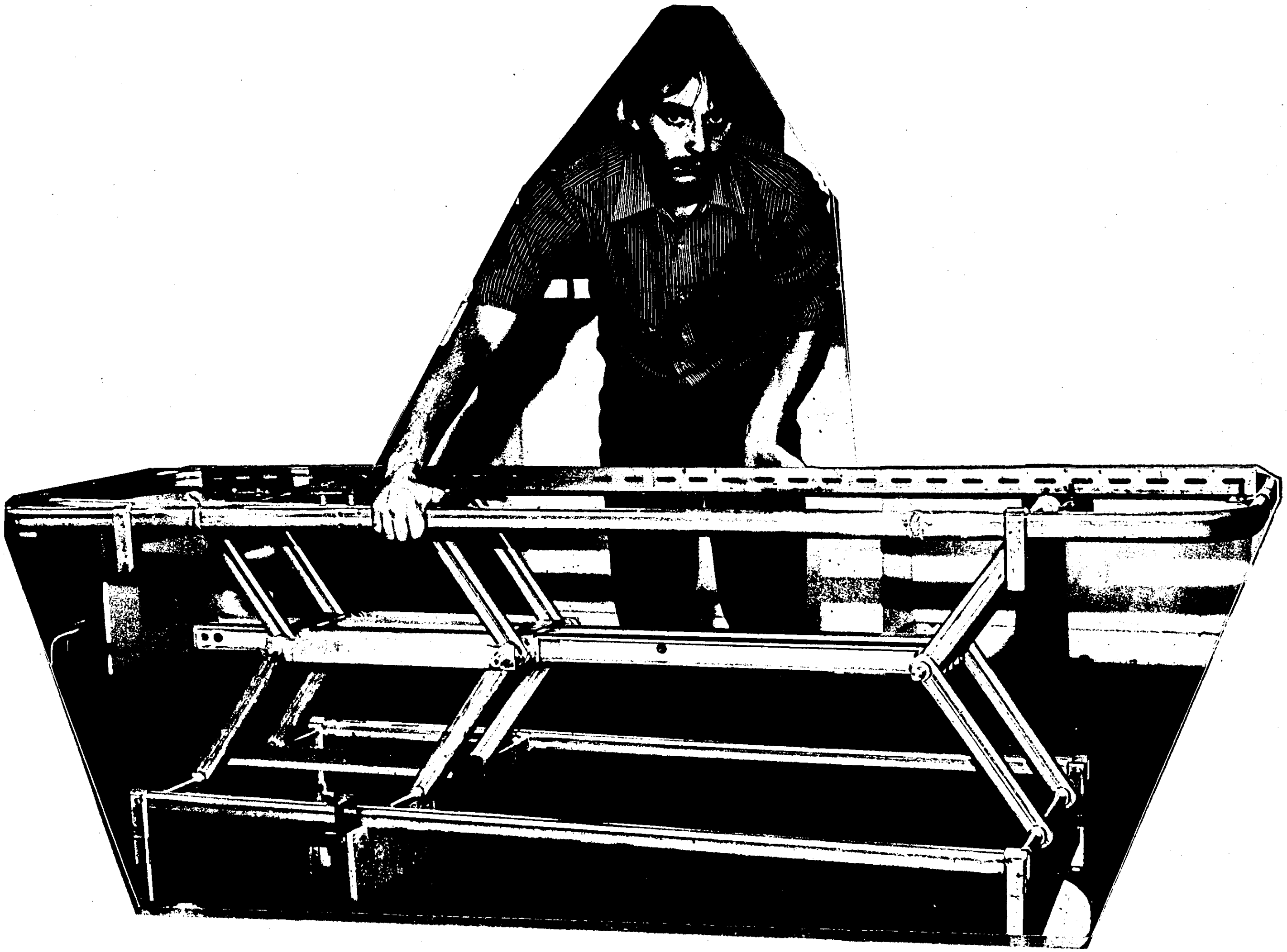
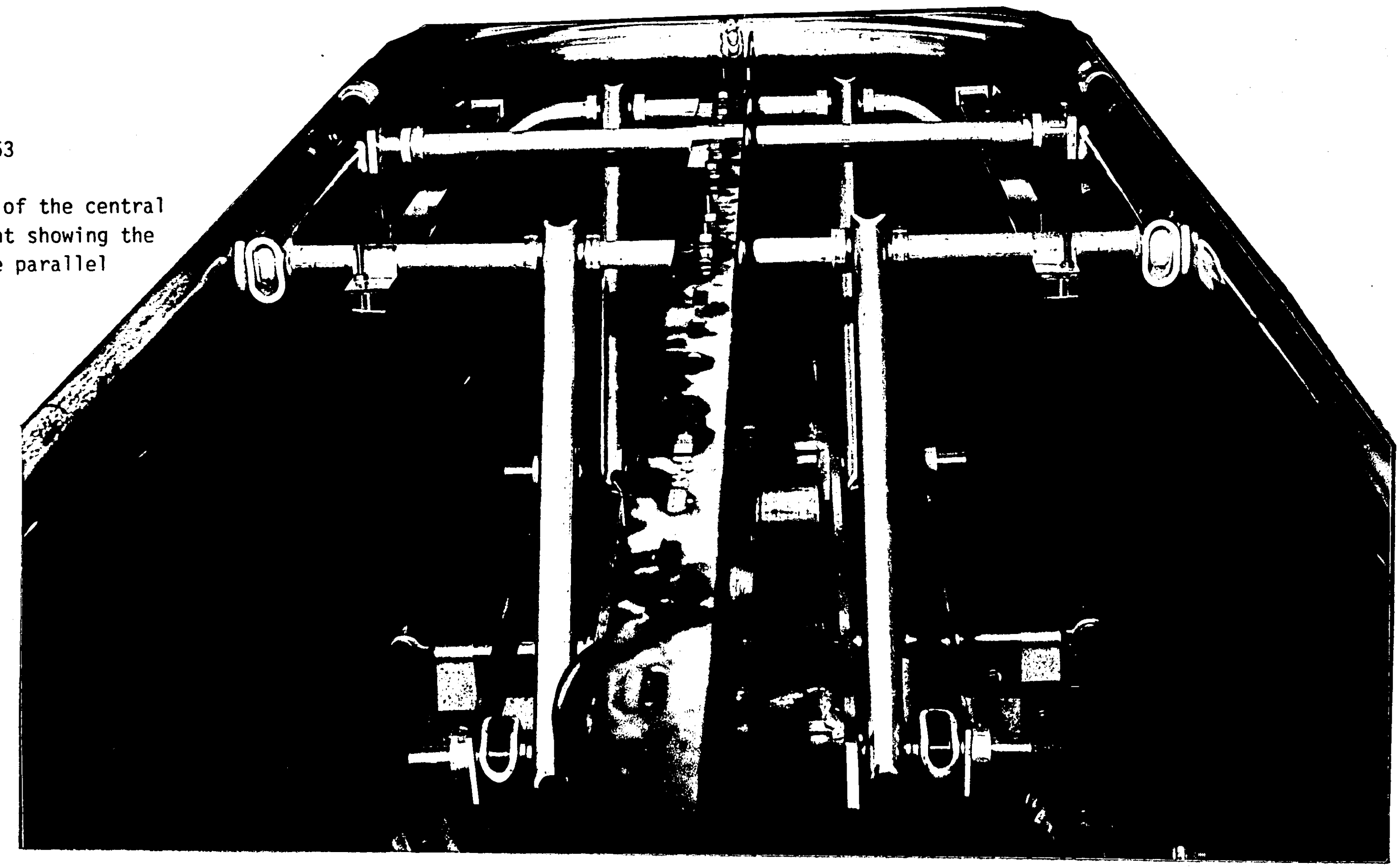


Fig. 62

Prototype 1 is being lifted to the elevated position. The central support/slide is shown with the tie bars holding the central parallel pivots at the correct distance apart for elevation. The chipboard and dexion formed additional stiffening to prevent looseness in the system due to weak components, later strengthened.

Fig. 63

A close up view of the central slide arrangement showing the carriage for the parallel leg unit.



lift is shown in fig. 60, however, after consultation with hydraulic systems engineers and obtaining quotations for the necessary cylinders and valves this system had to be abandoned on the grounds of the prohibitive price for the equipment, a cylinder would cost £58.00 and a 3 way valve £55.00, and the extra weight (9Kg) that would be added to the trolley unit.

4.3.8 This left no alternative to the mechanical device for controlling the elevating mechanism and again the ratchet seemed the only viable system. Several methods of using a ratchet system were proposed, two of which are shown in fig.61. The locking system was complicated by the combination of the Trendelenberg position with the elevating mechanism as two locks were required which would need simultaneous operation to achieve the Trendelenberg position but the operation of one lock only for elevation. However, none of these solutions were satisfactory being clumsy and requiring a complex mechanical linkage to operate them. The solution to the locking device was also dependant on the arrangement of the sliding mechanism and as ideas for this changed so did ideas for the locking device.

4.3.9 Prototype 1 was built using the initial ideas for a sliding mechanism where the double parallel set of legs were linked together to form a solid unit when only elevating the trolley. Fig. 62 shows the trolley being elevated and the link between the parallel legs can be seen. The parallel legs could be separated by the required distance to give either the Trendelenberg or anti-Trendelenberg position. The actual slide consisted of a carriage carrying the parallel legs with two nylon rollers attached to each pair of legs on either side running in a channel on each side of a central beam as shown in fig. 63. When lifted as

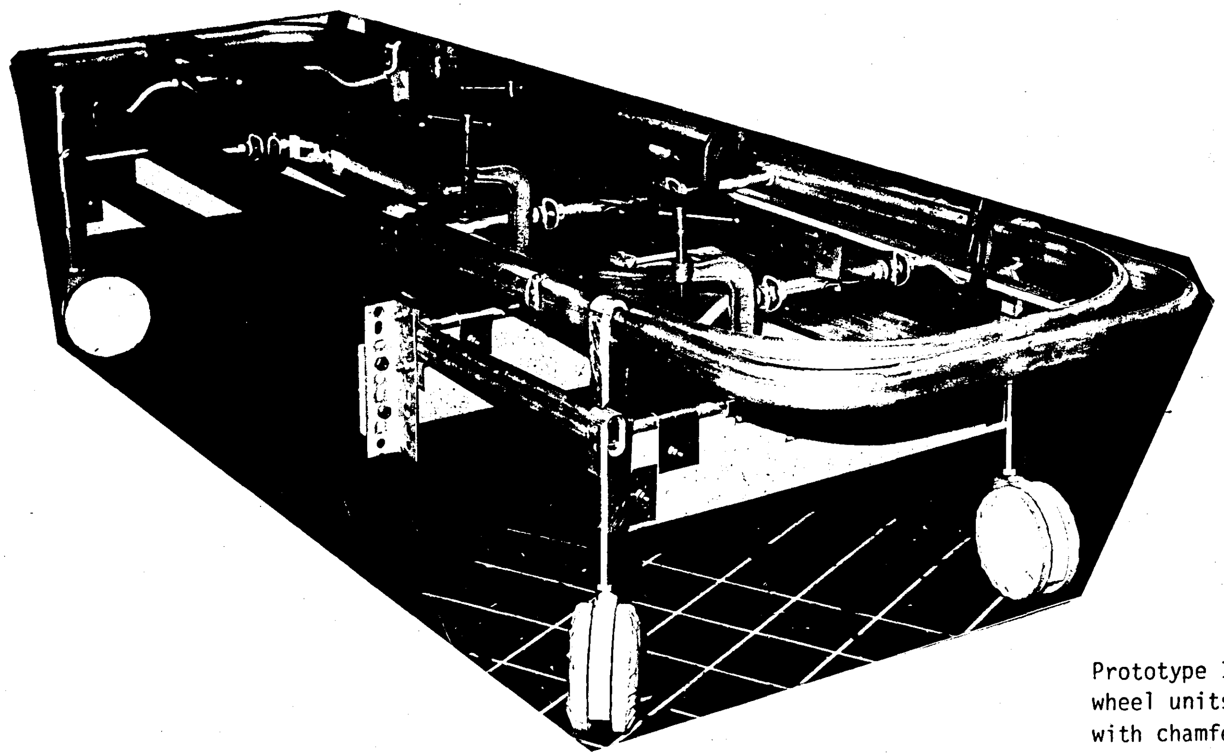


Fig. 64

Prototype 1 in the lowered position. The wheel units are based on a square shape with chamfered edges.

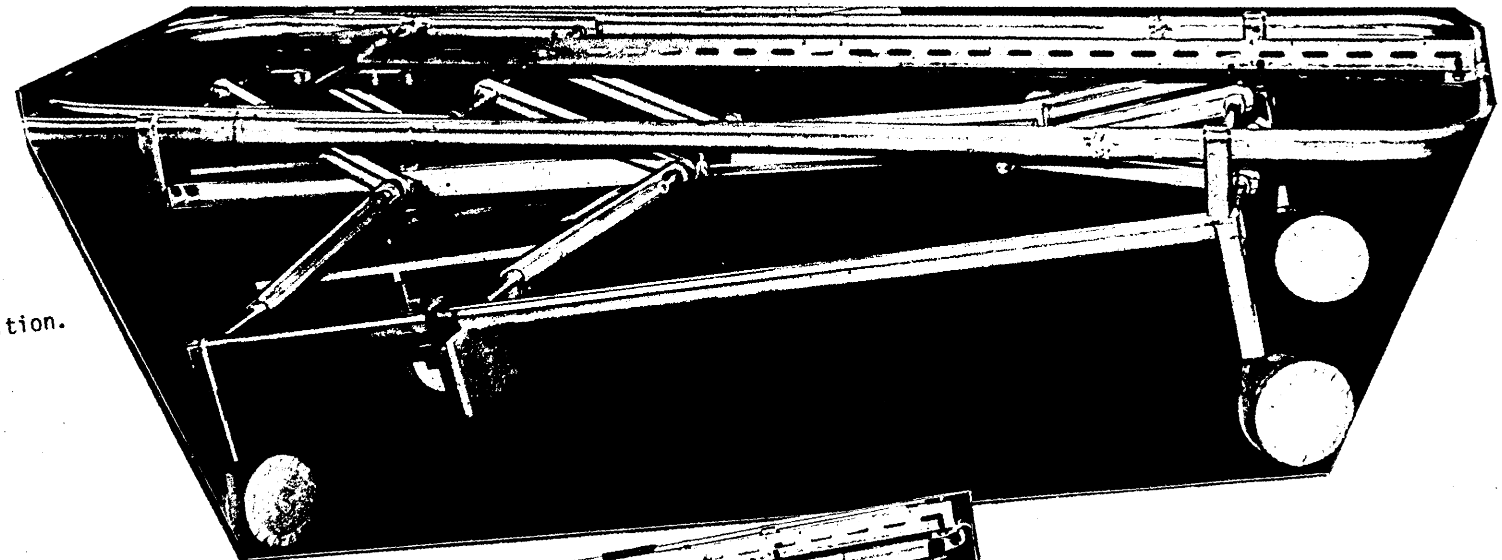


Fig. 65

The anti-Trendelenberg position.

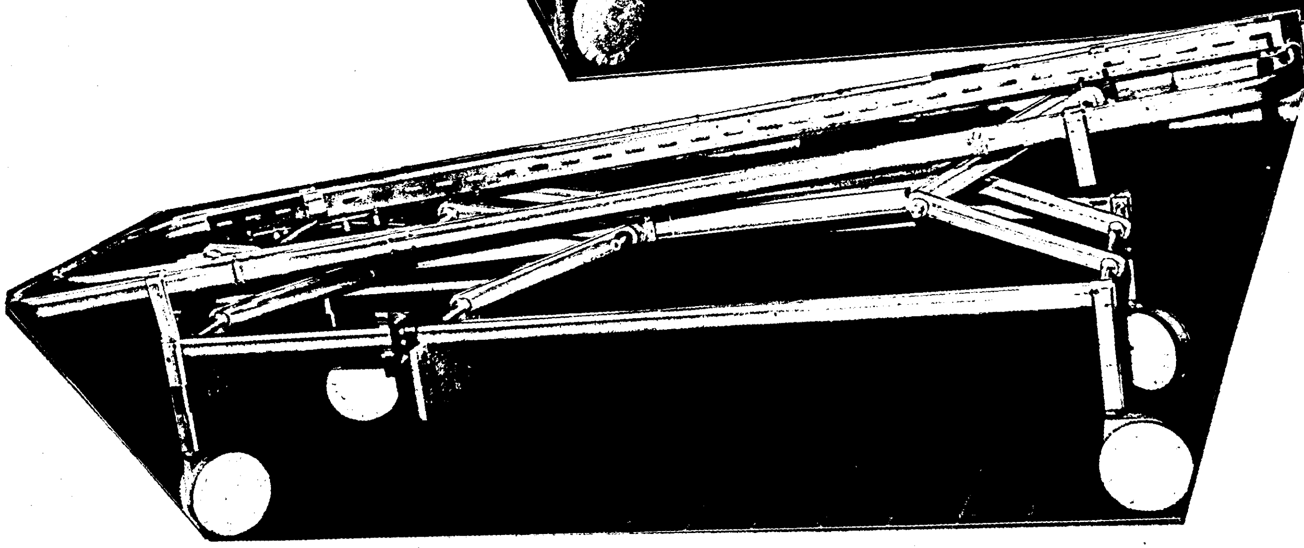


Fig. 66

Prototype 1 in the Trendelenberg position.

demonstrated in fig. 62 the trolley bed elevated and the legs straightened out attaining a more vertical position giving greater stability to the trolley. On lowering, the legs refolded to the original position as shown in fig. 64. With this system Trendelenberg and anti-Trendelenberg were achieved by altering the distance between the parallel leg units at the pivot points on the centre bar. When the distance between the centre pivots is increased the head could be raised to give the anti-Trendelenberg position shown in fig. 65 and when the distance was decreased the Trendelenberg was achieved as shown in fig. 66. The distance moved was determined by a slotted bar which enabled the correct angle of tilt to be maintained. However, as stated above it proved very difficult to design a satisfactory locking device that was compatible with the release/ locking mechanism for the elevating position.

4.4 The Backrest/Hyper-extension

4.4.1 As stated above (para. 4.2.5.) the backrest and hyper-extension facility were seen as one unit in the existing trolley design though there were no indications that the hyper-extension facility was used. The backrest, however, is one of the most used features on the trolley as every patient carried as a stretcher case required the side arms up and ususally the backrest adjusted to some angle from the horizontal. It is, therefore, very important that this feature should be reliable as the risk to patients already suffering from pain and shock would be unacceptable in the event of failure. It also required to be strong enough to support the heavier portion of the body weight that is distributed over it.

4.4.2 It was decided that the supporting system and locking device for the backrest required investigation

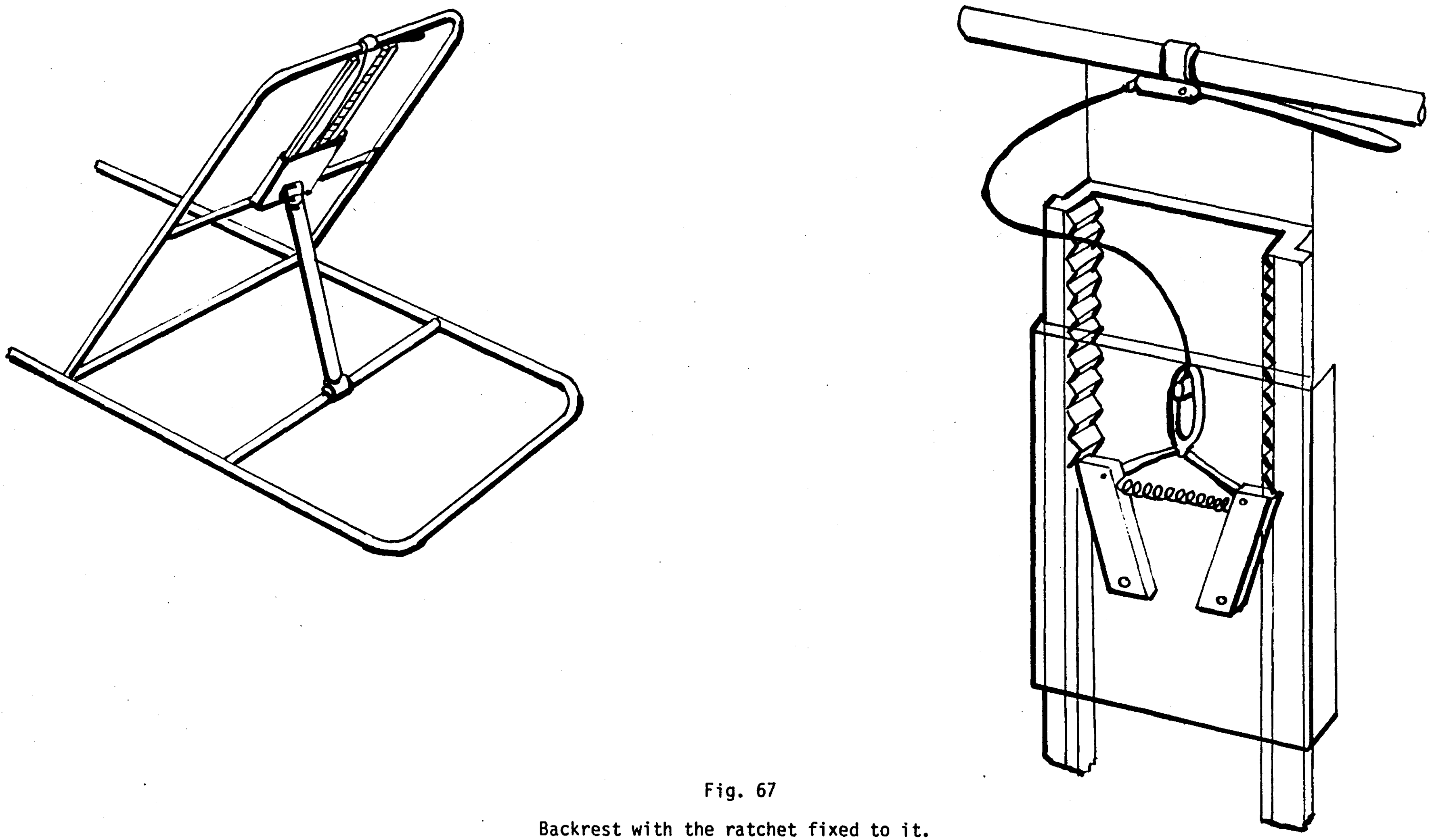
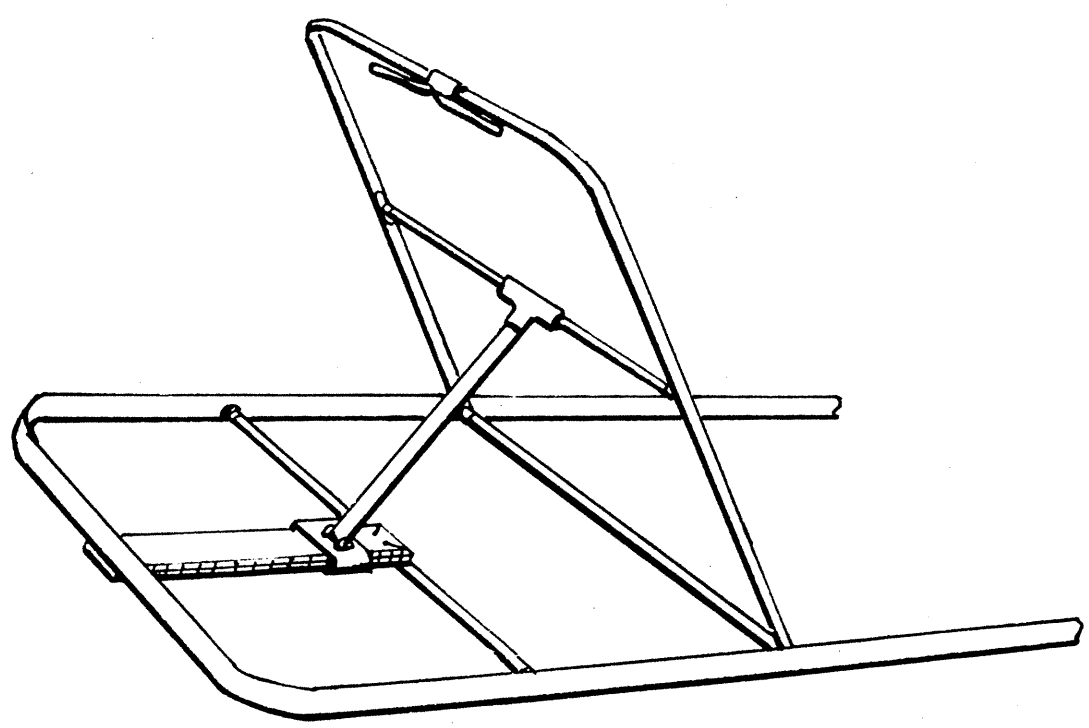


Fig. 67

Backrest with the ratchet fixed to it.



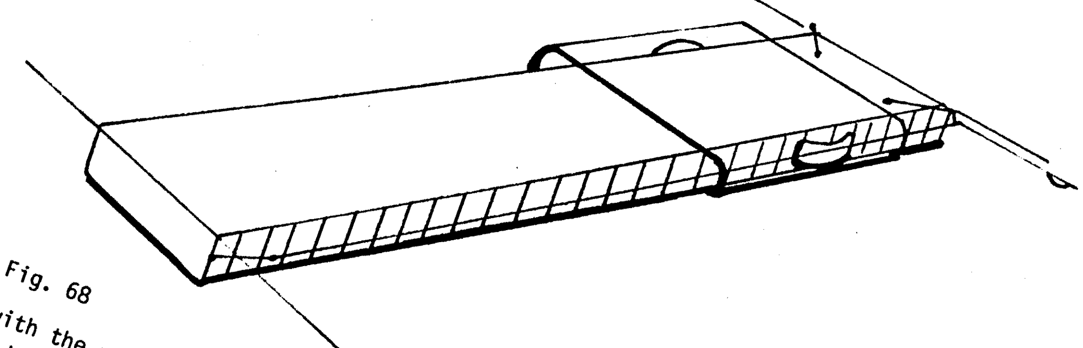


Fig. 68
Backrest with the ratchet
lock fixed to the top frame.

allowing for the possibility of incorporating the hyper-extension unit if necessary with the backrest. At first the position of the existing pivot points was retained as the pivot points for the new design. The supporting and locking mechanism is required to raise the backrest to at least 60° from the horizontal with a number of lockable positions between these points and to support the patient needing cardiac massage. Once again very limited space is available for the operation of the mechanism and it was required to fit around the pivot for the elevating mechanism yet allow the backrest to lie flat in the top frame when horizontal.

4.4.3 Ideas for this were generated, then assessed and the most promising ones developed to model stage. They fell into two main groups, those that required the pivot to remain on the top frame and to adjust the angle by means of a mechanism attached to the backrest, shown in fig. 67 and those that pivoted about the backrest and were adjusted on the top frame as shown in fig. 68. It was found that both methods of operation had major problems to be solved. The ergonomic requirements for operating the backrest indicated that the operating lever should be fitted to the outer frame of the back-rest where it should be easily accessible. Where the design involved the moving element attached to the backrest it was complicated by the probable incorporation of the hyper-extension position and by the nature of the moving parts which made the release mechanism difficult to operate. It was decided,therefore, to examine in greater detail the alternative position. This involved the attachment of the moving parts to the top frame with the support pivoting about the backrest frame which simplified the release mechanism as it could be attached to the support and move with it so

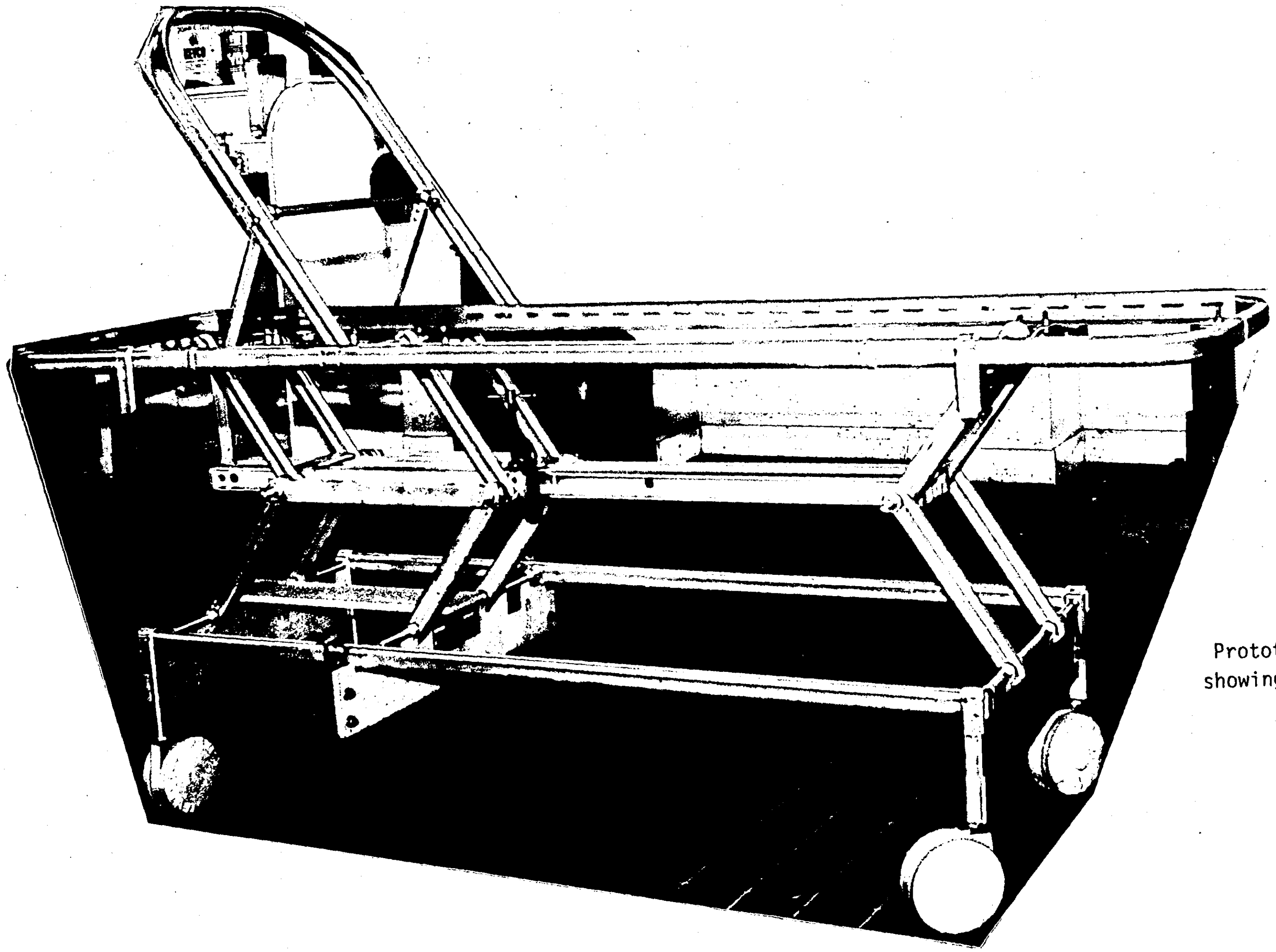


Fig. 69

Prototype 1 with the backrest up showing the two supports.

keeping a fixed length. However, the major problem consisted of the positioning of the slide attachement in such a way that there was no interference with the elevating mechanism, no danger of trapped fingers during use of the trolley and adequate movement to allow the correct maximum angle to be obtained.

4.4.4 On examining the support system it became necessary to decide on the merits of one central support as opposed to two side supports. The two side supports gave better stability than the central support and could be fastened directly to the backrest framework without requiring a separate pivot bar, whereas the central support could be more substantial and would require only one release/locking mechanism. The type of support and its use would affect the design of the locking device as the ergonomics indicated, from the actions required, that it would be preferable to be able to lift the backrest freely without operating a release mechanism, but the release should be operated to lower it. This indicated some form of friction or ratchet device. Friction devices were developed as being preferable for their quietness and the infinite number of positions obtainable within the distance specified, but after mock-up trials these were rejected as being unreliable and likely to slip on wearing. This left the ratchet device which, though noisy, could be relied on to return to its 'on' position on releasing the lock release lever and they do offer a number of positions within the required angle range.

4.4.5 It was finally decided that Prototype 1 should have a two side support system running on two slides attached to the top frame as shown in fig. 69. As the slides for the backrest were required to work above any pivot for the elevating mechanism this complicated the top front cross

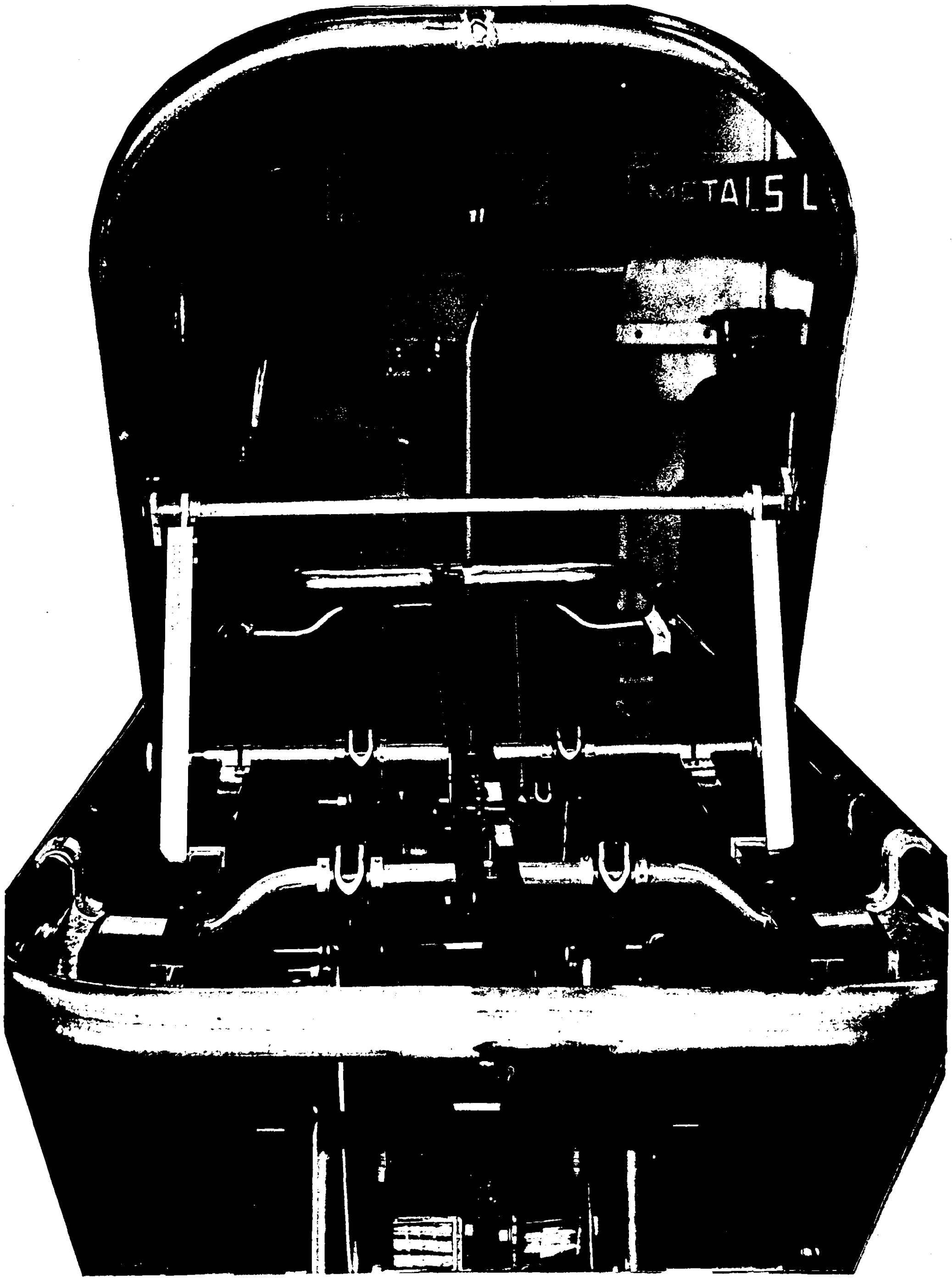


Fig. 70

A close up of the backrest support system showing the pivot attached to the backrest and the sliders on the horizontal slides. This illustration also shows clearly the cranked cross pivots supporting the legs for the elevating mechanism.

pivot bars for the elevating mechanism which were then required to have a crank in each end, just before the casting were attached, in order to accommodate the slides. The supports were attached to the slides by small sliding units which had nylon blocks attached and moved over the 'I' section aluminium used for the slides which is shown in fig. 70. This system would have required two locking devices operated simultaneously.

4.5 Wheel Units

4.5.1 This title includes the actual castor and the supporting castings that enable it to be attached to the main framework. In the existing trolley the castors are exceedingly strong but also very heavy and there are problems with the operation of the locking device. It was felt that this was an area in which weight could be saved by the use of a different castor and an examination of those avaiable with the equivalent specification and with a diameter of 125 - 150mm was undertaken. The castor finally selected was the 'Travelaid 125' by British Castors, for its light weight, smooth sides without any protuberances that may catch on parts of the ambulance or building in which it is used, and its clean aesthetic appeal. The locking device for this castor is intended to be incorporated within the castor housing but is still in prototype form, and not yet available on the market.

4.5.2 The supporting castings are required to accommodate not only the castors but to provide fixing points for the cross pivot bars that support the elevating mechanism. They are required to provide the locking point for the location of the trolley within the ambulance and the supporting points between the top and bottom frame when the trolley is in its lowered position. It was also necessary to

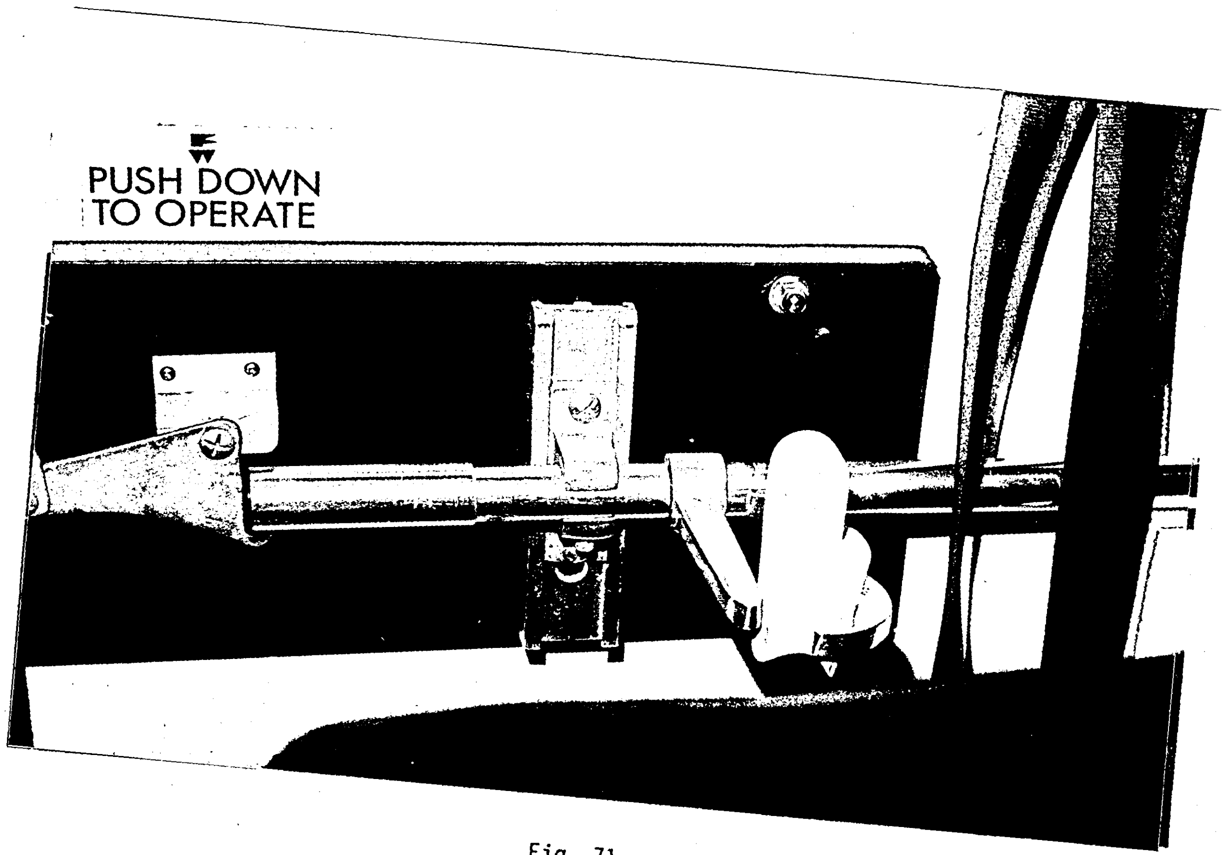


Fig. 71

The wooden mock-up of the top wheel unit casting was taken to the ambulance station for trial on a trolley lock in the ambulance.

provide some means of locating the two sections of the supporting casting to avoid movement when the top frame was lowered onto the lower frame and to provide a pivot about which the Trendelenberg position could be maintained. The supporting castings had to accommodate the shapes of the materials that would either be fastened to them or that they would be fastened to. These comprised the flat oval tube of the lower frame to which the casting required firm fastening as this formed the main connection between the wheel unit, the main frame and the cross pivot bars. These castings had also to incorporate a shaped section to fit the locking device in the ambulance which is designed around a 32mm maximum diameter circle. With all these different shapes to accommodate it was initially felt that the top sections of the casting which are attached to the frames should retain a rounded rectangular look which extended into the portion of the casting that housed the cross pivot bars. Fig. 71 shows the upper portion of the wooden model being tried in an ambulance lock. This rectangular section was then tapered into a round leg which terminated in the fastening to the castor.

4.5.3 On assessing the wooden model of this shape it was decided that the aesthetic proportions would be better appreciated if the previously round lower leg remained as a rectangle with the corners chamfered and tapered to a square at the castor fastening. This can be seen in fig. 64. The section of the casting fastened to the top frame was also treated as rectangular and the edges chamfered and this was formed with a stop to prevent the backrest from falling through and an extension also square but chamfered that met the lower section and was located by the meeting of two single-direction curved surfaces which are also shown in fig. 64. This shape was developed from the wooden model to the design used on Prototype 1.

4.6 Carrying Handles

4.6.1 In the existing trolley these comprise telescoping poles with plastic handles at the outer ends. Numerous problems were reported concerning these and it was felt that different ways of achieving this function should be examined. It also seemed appropriate that as some problems are due to the position of the centre of gravity of a patient on the trolley, the position of the handles should be examined to determine the best handling position to overcome this.

4.6.2 The carrying handles need to be long enough to enable the person at the head to bend over between them while lifting the trolley and for the person at the foot end to see where they are going and to avoid hitting the feet of the casualty. The handles also need to be capable of being stored when not in use so that they do not catch on any parts in the ambulance nor interfere with walking when the trolley isbeing pushed. Examination of the ideas formulated showed that there are only two main methods of achieving these criteria.

1) Telescoping handles
2) Folding handles

It was decided to examine carefully the possibility of attaching the handles to the top frame, nearer the centre of gravity, to reduce the possibility of overturning if the trolley is tipped or the patient moves suddenly. To enable the handles to be accommodated on the top frame the folding version would be required as the outer curves would not allow the fixing of a telescoping version. However, after serious consideration and building mock-ups it was decided,that though preferable from the ergonomic aspect, it would not be possible to use the handles on the top frame because of the

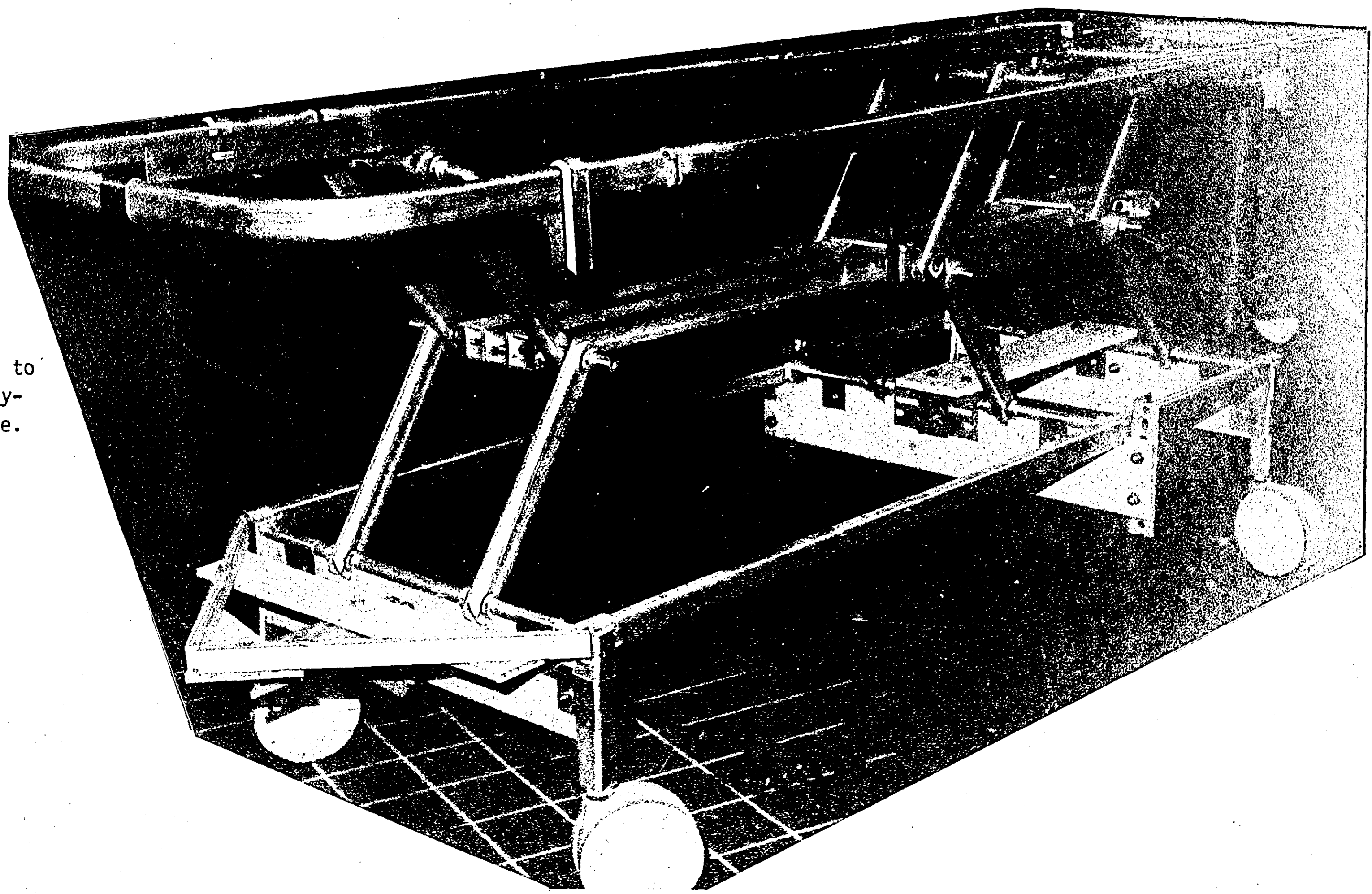


Fig. 72

This shows the test rig used to test a poaition for the carrying handle on the lower frame.

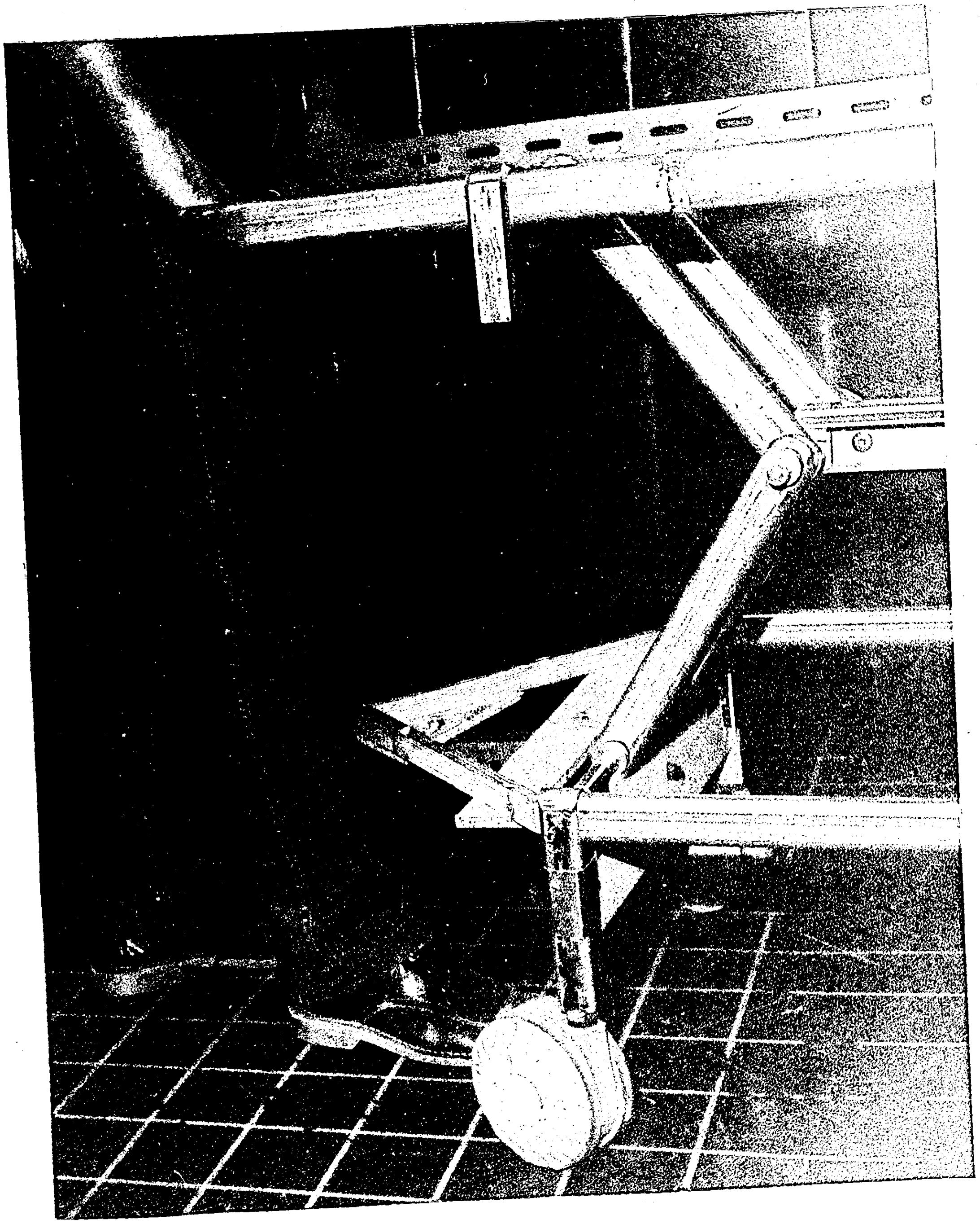


Fig. 73

Testing the carry handle position for leg interference while pushing the trolley.

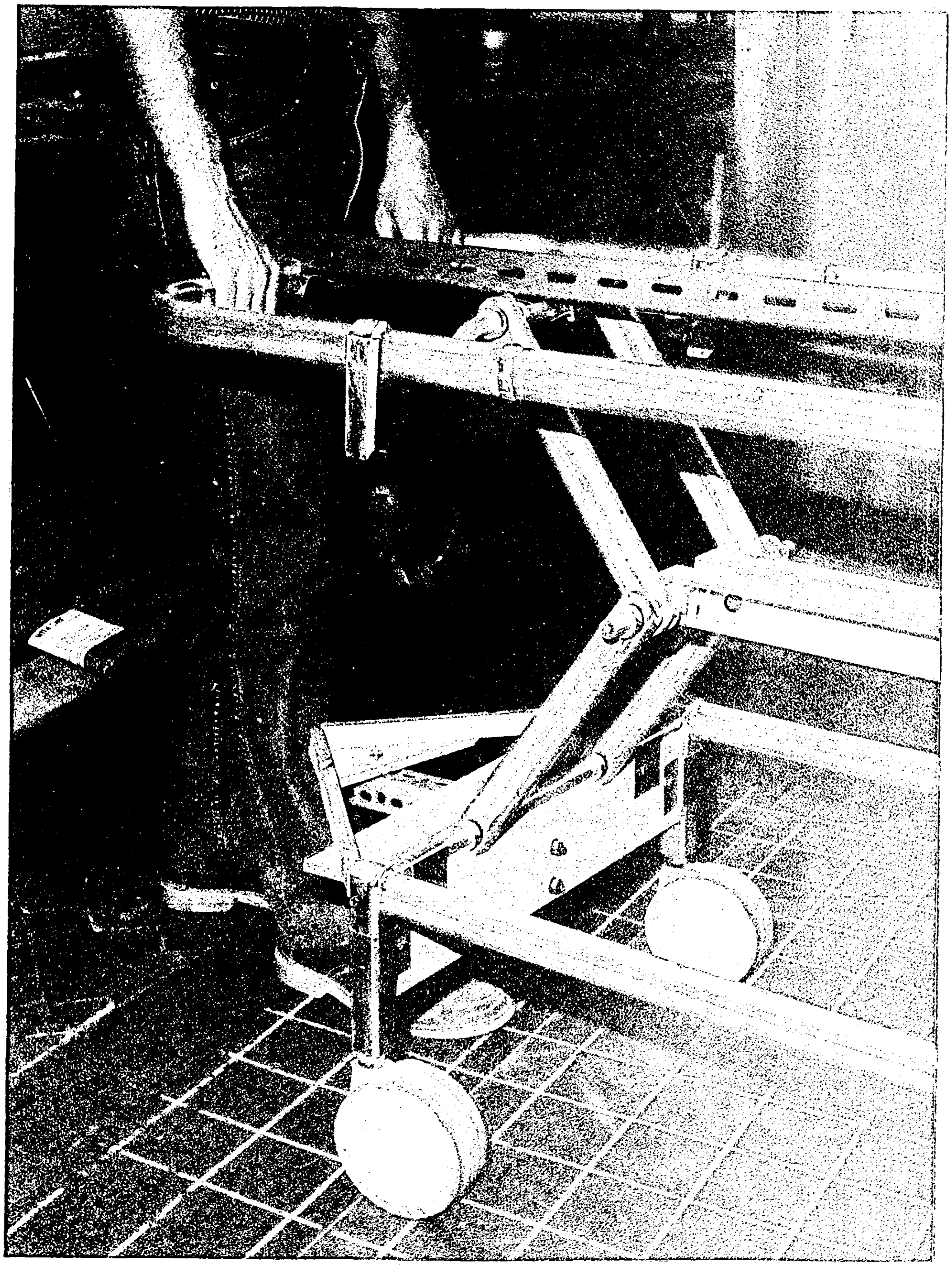


Fig. 74

This showed that there would be leg interference.

restriction of space, the nature of the elevating mechanism and the need to be able to use all the facilities on the top frame without having to move handles. It was also felt that the extra lifting height required to put the trolley in the ambulance would be unacceptable. It was decided, therefore, that the handles would need to be located on the lower frame.

4.6,3 Once again the question of which version to use arose and after consideration the folding type was selected because the flat-oval section would make the use of a telescoping handle within the lower frame difficult and would complicate the fastening of the wheel unit casting to the lower frame. It became necessary then to consider possible ways of storing a folding handle when not in use and of suitable length to enable the trolley to be easily handled. A variety of ideas were examined and a test rig built of one of these ideas as shown in fig.72, but this proved likely to obstruct walking when pushing the trolley as seen in figs. 73 & 74. This test rig was built onto Prototype 1 and constituted the stage that the design of these components had reached when Prototype 1 was evaluated.

4.7 Fowler's Position

4.7.1 This feature is used to maintain the knees in an elevated position but because of a variety of problems is seldom used. On the existing trolley operation is by a handle which is pulled out under the foot end of the trolley and turns a horizontal screw which slides the end of the trolley inwards pushing the linked sections upwards to give the elevation. As this mechanism is ineffective it was decided to examine other methods of achieving this position while also considering the position of the handles in relation to all the other mechanisms and to the handling requirements of the other functions.

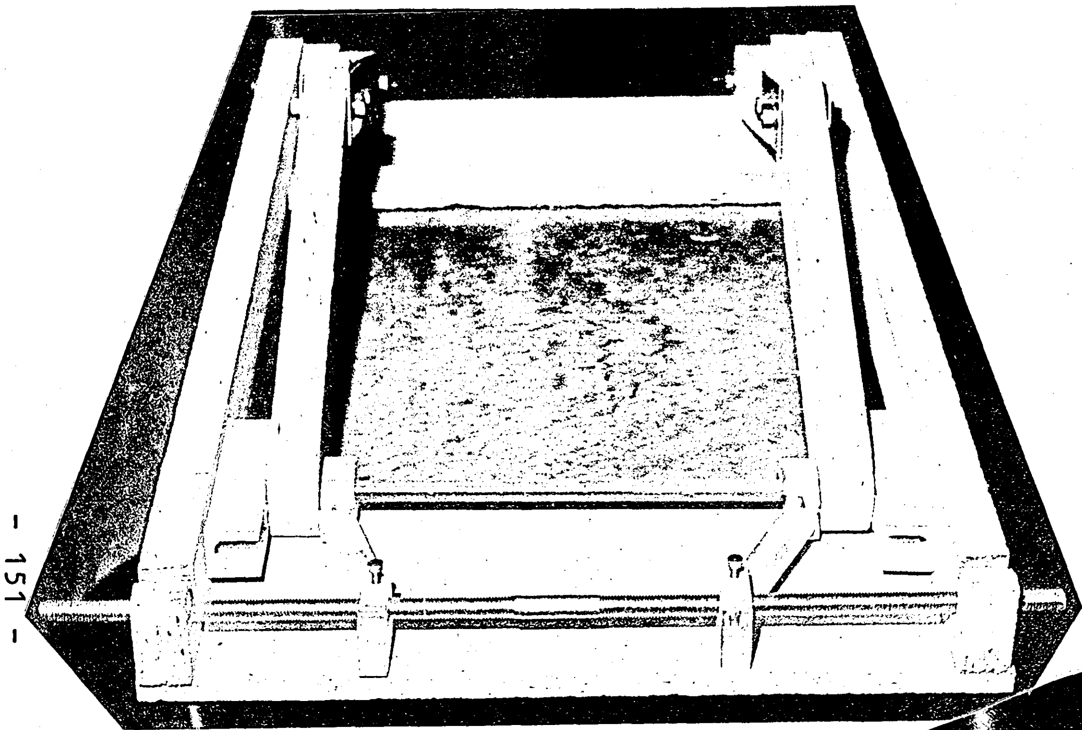


Fig. 75

A test rig for the Fowler's position showing a mechanism using a right and left handed screw thread to operate the slide/lifting device.

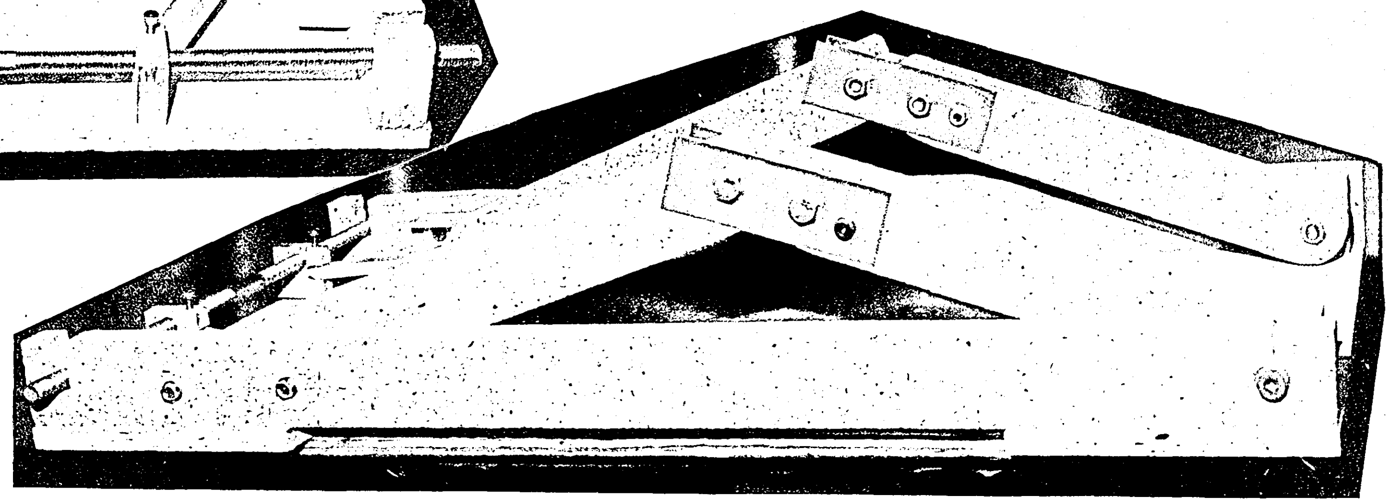


Fig. 76

Side view of the test rig.

4.7.2 As before many ideas were formulated, then assessed and the more promising ones developed further. It seemed logical to achieve better mechanical advantage by directly lifting the knees so ideas were developed to enable this but were then rejected as the lack of space limited the movement of any vertical mechanisms. This left once more operation in a horizontal plane as seemingly the only possible means of achieving the elevation.

4.7.3 One possibility considered pulling the foot end of the section towards the middle by using a horizontal screw with opposite threads on either side placed across the trolley so that operation of the facility could be carried out from either side, Two levers attached to the screw and to the foot end of the section as shown in fig. 75 could then be moved across the screw by turning it and, depending on the direction of rotation, the distance moved by the levers from the centre pushed the loer leg section away from the screws and raised the centre as seen in fig. 76. This idea was developed from an earlier idea that used the left and right hand threaded screw to raise the centre linkage directly but the space required to accommodate this was greater than that available. The problem with this system, however, involved the actual operating handle. If this was made removable then there would be a high chance of its being lost, but should the handle remain on the screw bar then two would be required and some means of turning one without the other would be needed. This function was not included in Prototype 1 but was developed further from this stage to be built in Prototype 2.

4.8 Side Arms

4.8.1 As these provide the most obvious security of which the patient is aware it was considered

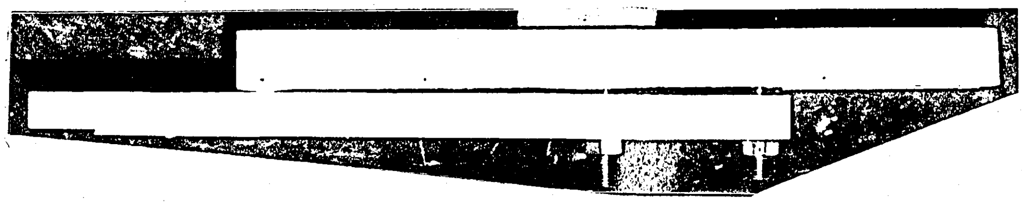


Fig. 77

Test rig for the side arm slide mechanism with the arm folded.

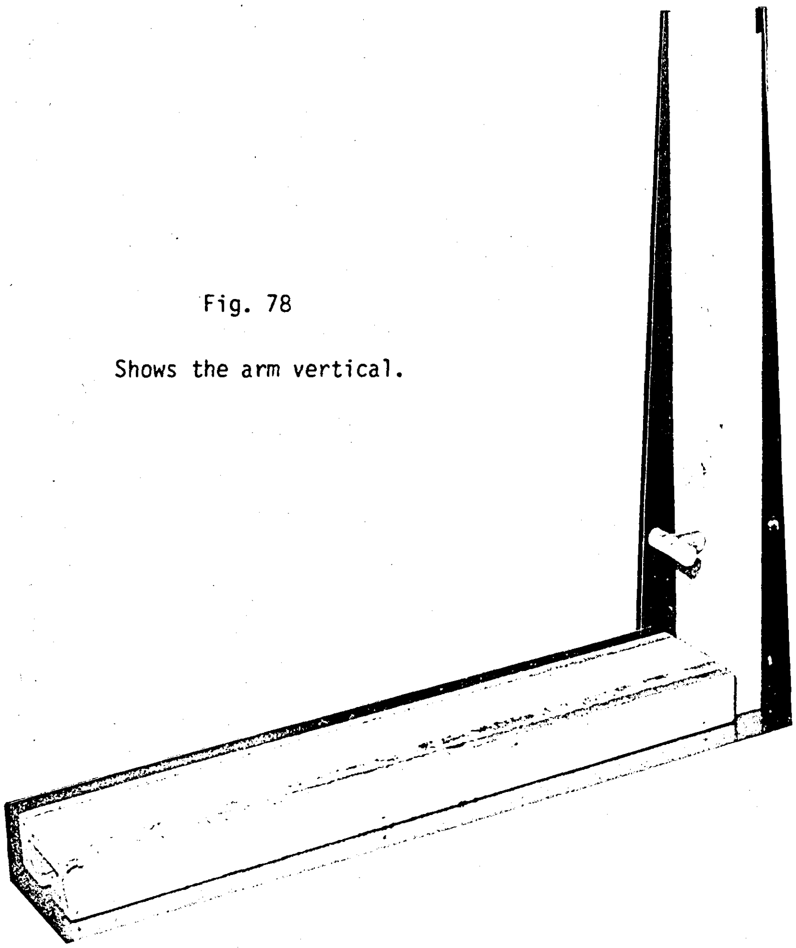


Fig. 78

Shows the arm vertical.

important to try and improve on the existing performance. The problem with the existing design arises from the length and height of the arms which is dictated by the nature of the design and the storage position of the arms, as well as the position of the trolley in the ambulance and the position of the arms in relation to other facilities on the top frame. It became necessary, therefore, to examine ways in which the height and length of the arms could be increased without encountering the problems of the existing design.

4.8.2 The ideas examined looked at the various ways of achieving this and involved the use of telescoping arms that would enable two heights to be used, double hinged arms that would have the same effect and arms that could be raised one end at a time to give a sloping surface for easier access to the patient if necessary, however, these were all rejected as complicated and unsatisfactory solutions to the problem. As these all worked by swinging through an arc from one vertical plane to another it was felt appropriate to look for a solution that would enable the arms to be stored in another plane from the vertical. The only solution, therefore, appeared to be that of storing the arm under the trolley in a horizontal position. This could be achieved by using a slide under the trolley that enabled the arm to be pulled out then swung up into place and locked there. Fig. 77 shows a mock-up of the arm folded and fig. 78 shows it in a vertical position. This idea had the limitation that the height of the arm was dictated by the space available under the trolley but this still enabled the arm to be higher than that on the existing model. This also was not used on Prototype 1 but was developed further for Prototype 2.

5 FIRST PROTOTYPE - Construction & Development

5.1 Introduction

5.1.1 Although the functions described in Chapter 4 were designed as individual items they were considered within the context of the whole and Prototype 1 was constructed at this stage to enable some of these ideas to be tested in 3-dimensional working form prior to further development or re-design as necessary. The construction of the prototype took place in four main sections which, although separate developments, interacted and overlapped each other during the whole process.

5.1.2 The first major problem to be encountered in the development of the prototype was the difficulty of obtaining the required section in the specified material. The design was based around a flat-oval tube made as an alunminium extrusion which will be three to four times cheaper than the drawn tube used at present and will enable the exact shape required to be designed. It was recognised that the grade required for a production version would not be available for the prototype as this would require the design of a die and the manufacture of a minimum quantity, however, it was felt more important to have a representation of the section required than the grade but this proved impossible to buy in small quantities. The problem was finally solved by obtaining ex-stock tubular material which was then heated and rolled to the required section in the Polytechnic workshops. Once the material had been produced it was possible to proceed with the prototype construction.

5.2 Top Frame Construction

5.2.1 The top frame basically consists of a rectangular frame with large radii at the corners. This was very simple to make once the initial problem of bending the radii for the corners had been resolved. This was achieved by making a former that gave the correct radius when the tube was filled with sand, plugged and bent through the required angle. As it was difficult to fill and plug long lengths of section it was decided to make four corner pieces which were cut to length to give the required width across the trolley and joined to the two straight side pieces to give the required length. These pieces were then welded together to form the frame with the depth of the flat-oval section in the vertical plane to give strength in the required direction.

5.2.2 Further modifications to the top frame took place during the development of the elevating system as it was necessary to devise and make the fastenings that enabled the cross pivot bars to be attached to the top frame. As stated previously (4.5.2) the wheel unit castings, the upper portions of which attach to the top frame, carry the cross pivot bars at each end but the pivot for the double parallel unit was integrated with that of the backrest and attached to the top frame by the nylon bushings that carried the backrest. All these fittings were attached to the frame by through bolts.

5.3 Lower Frame Construction

5.3.1 The lower frame consists of the two side rails held apart by the cross pivot bars that carry the elevating mechanism. Main work on this related to the fastneings that enabled the cross pivot bars to be attached to the sides of this rail forming a rectangular framework. Again as mentioned in para. 4.5.2. the wheel unit castings formed the attachement points for the head and foot end pivot bars and a special fitting was needed for the pivot carrying the second part of the double parallel unit.

5.4 Elevating Mechanism Construction

5.4.1 This was designed around the central slide/ support bar and comprised the legs forming the parallel and single units which at one end pivoted about the cross pivot bars on the top or lower frame and at the other end pivoted about a spigot attached to the central bar. The legs were made from the flat-oval section and had each end radiused to allow turning without catching on objects above or below the trolley. As these legs were required to turn about the pivots nylon bushings were fitted to prevent binding between the aluminium surfaces. The central slide/ support was constructed as simply as possible from three lengths of channel bolted together as shown in fig. 72 with the outer sections forming the slide for the carriage carrying the double parallel unit. The carriage as described in para. 4.3.9. consists of the double parallel leg units attached to nylon rollers, and held the correct distance apart by a bar slotted to allow the use of the Trendelenberf position as shown in fig, 63.

5.5 Backrest Construction

5.5.1 The framework of the backrest consists of a flat-oval open ended rectangle with radiused corners. Again a special former had to be constructed to enable the correct radii to be obtained. As the backrest was assembled complete with the cross pivot and elevating mechanism, the framework had to be made simultaneously with the top frame.
The development of the locking and operating system was added tp the prototype after assembly of the main sections.

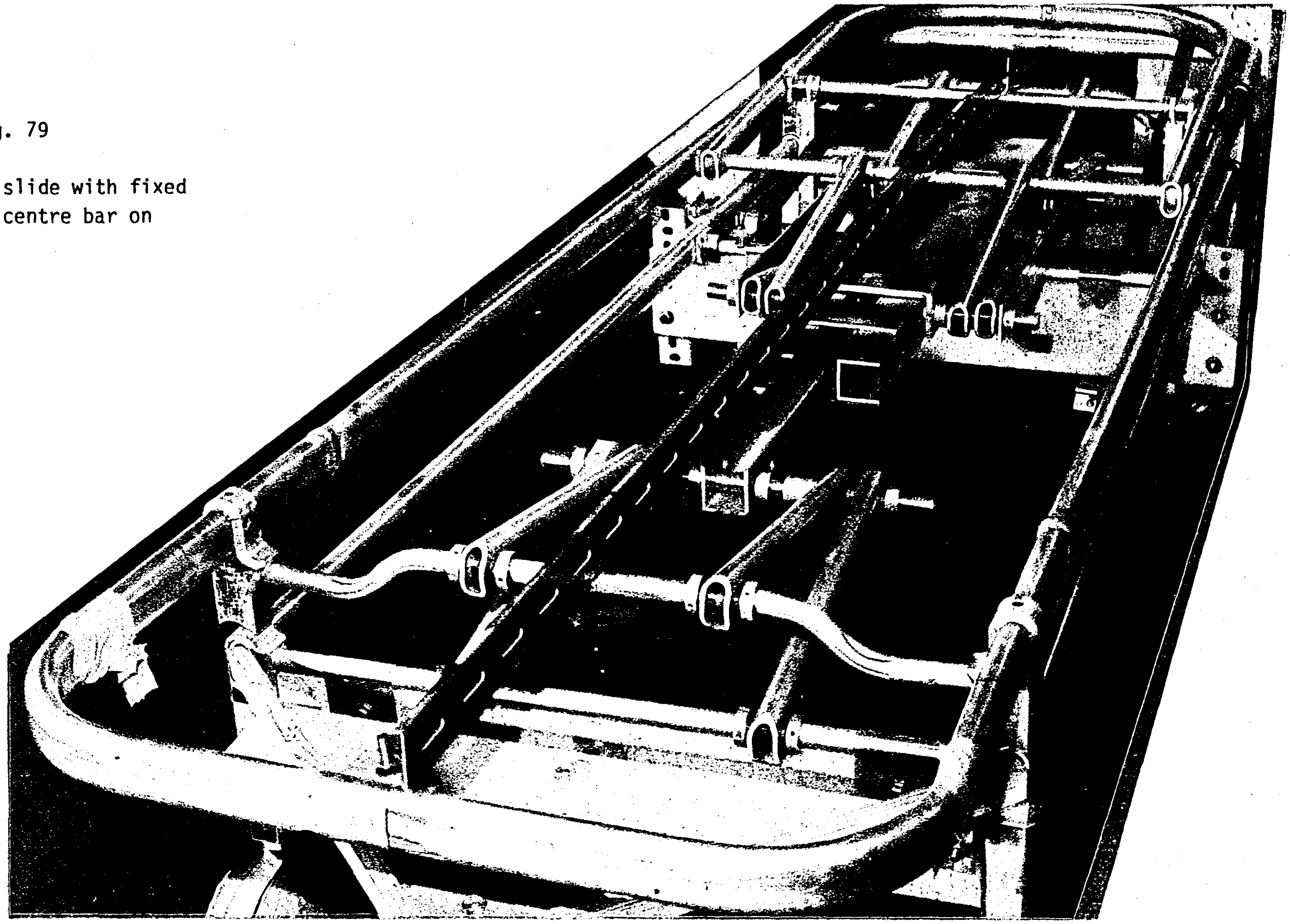


Fig. 79

The revised central slide with fixed carriage and moving centre bar on Prototype 1.

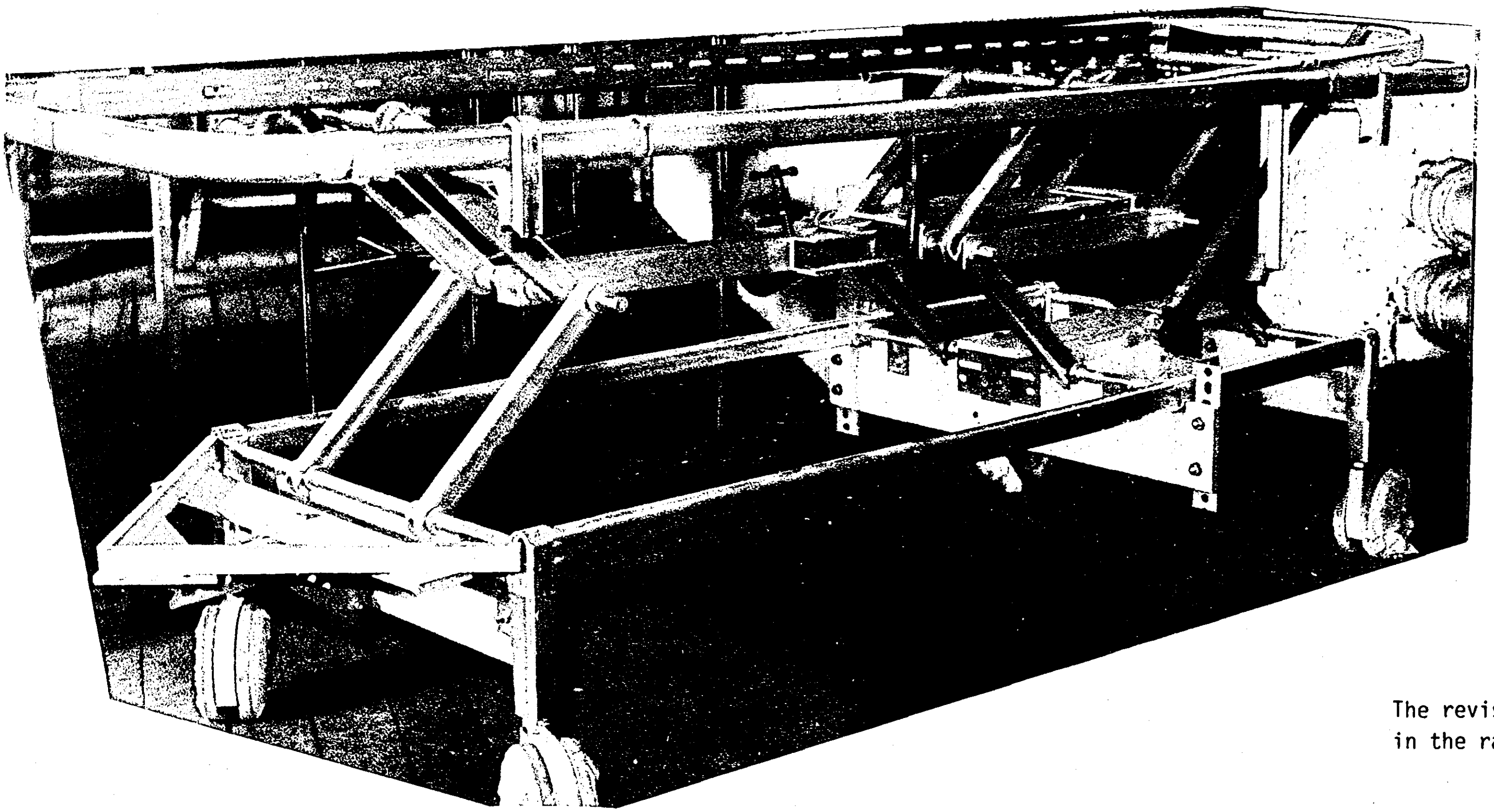


Fig. 80

The revised elevating mechanism
in the raised position.

5.6 Prototype 1 - Development

5.6.1 This prototype was developed and used to examine the basic form and operating priciples of the main functions. On elevating the trolley for the first time it immediately became apparent that there was considerable looseness in the elevating system. In experimenting with the system it was discovered tha though loose fitting joints accounted for some of this movement, the main cause was the turning action that the legs exerted on the cross pivot bars forcing these to bend and rotate about the wheel support castings. When reinforcing braces were fastened to these to reduce movement the mechanism was stiffened considerably.

5.6.2 Though the frame had been stiffened by the addition of braces the central slide/support bar remained loose and the rigidity of this increased by fixing the distance between the central pivot of the double parallel legs locking the Trendelenberg adjustment into the horizontal position as show in fig. 63. However, on examination it was decided to re-develop this unit to lighten the weight by reducing the material used and to simplify the operation. This was achieved by immobilising the carriage and obtaining elevation by sliding the centre section of the central support unit in or out between the outer channels as demonstrated in figs. 79 & 80. Limited movement of the central pivots allowed the distance between the parallel legs to be adjusted to obtain the Trendelenberg or anti-Trendelenberg positions. Fig. 81 shows the position of the stop relative to the carriage when horizontal and fig. 82 shows the distance the carriage moves in the Trendelenberg position. This improved version had the advantages of minimising the moving parts, reducing looseness, providing a more rigid unit and reducing weight. However, after consideration of the problem

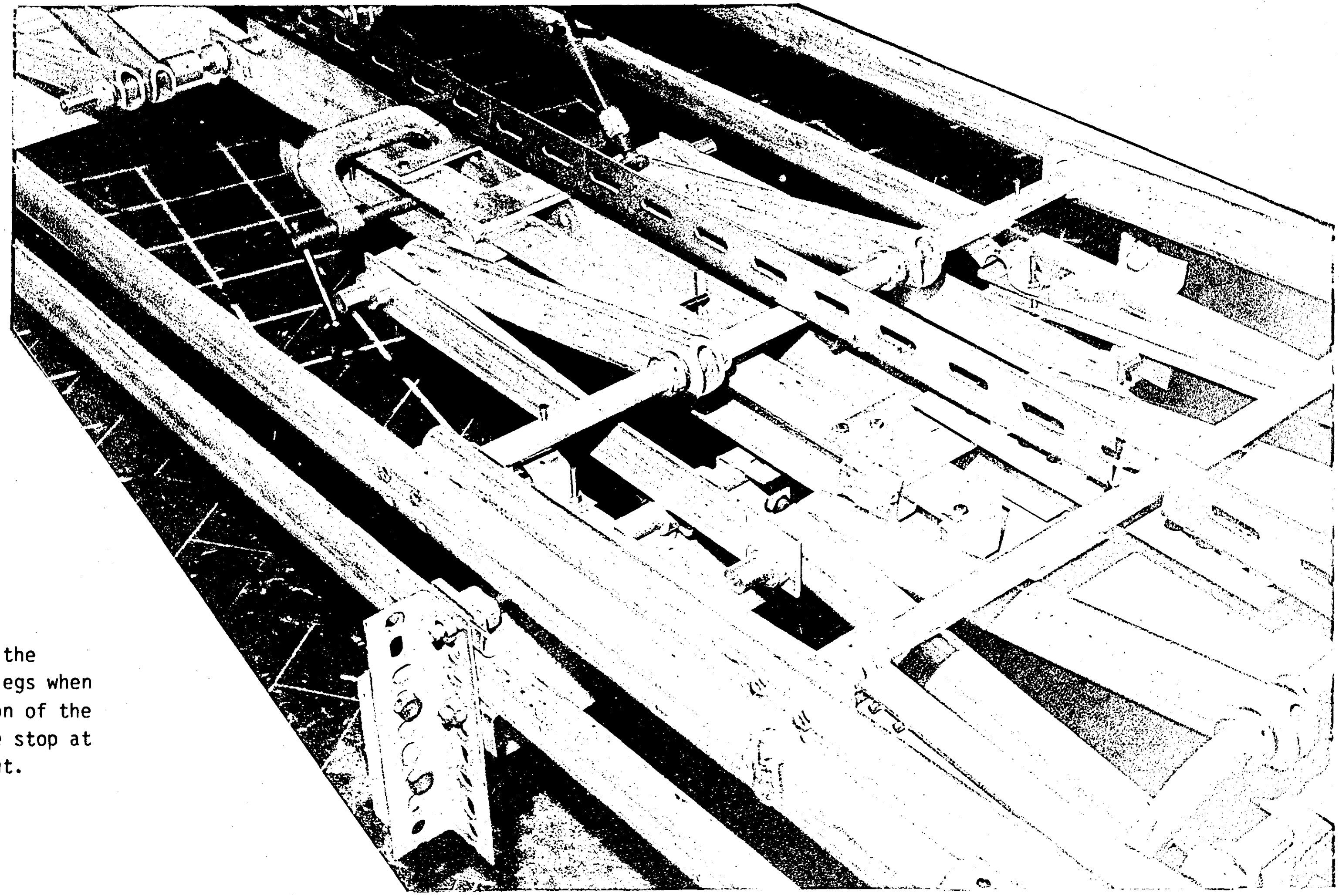


Fig. 81

This shows a close view of the carriage for the parallel legs when lowered. Note the position of the carriage in relation to the stop at the end of the central strut.

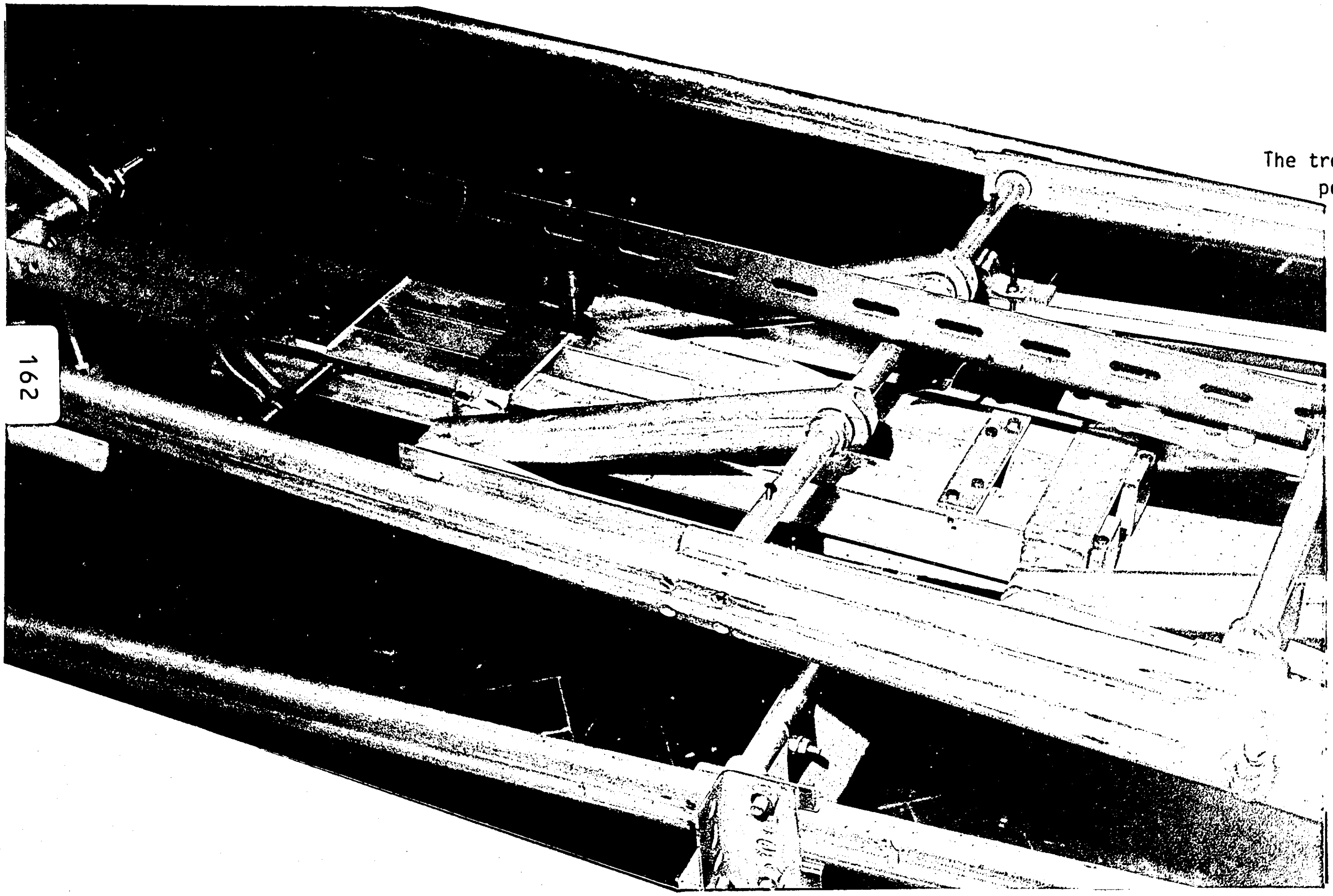


Fig. 82

The trolley in the Trendelenberg position. The carriage is now against the end of the central strut which allows the pivot points to move apart for the trolley to achieve this position.

involved and discussions with representatives of F.W. Equipment Co., Ltd. it was concluded that the integration of the Trendelenberg operation into the elevaging mechanism would not be feasible as when elevating the trolley while in the Trendelenberg position the angle changes with height from the required 12° to 5° of tilt. It was considered important that this angle should remain constant therefore a separate means of obtaining the Trendelenberg position was needed. Another factor contributing to this decision was the difficulty of designing a satisfactory but simple locking system for the integrated mechanism. Separating the two systems simplified the problem though it seemed likely to increase the weight of the trolley by requiring the addition of extra components.

5.6.3 On elevating the trolley bed the legs straightened and the angle between them at which the maximum height was obtained was arbitrarily set in the first design. However, it was recognised that there would be a maximum angle at which the legs would re-fold easily and which if increased would result in them remaining straight. Prototype 1 was used, therefore, to test this angle which was found to give the best performance 60° from the horizontal or 120° between the legs at the centre.

5.6.4 The backrest mechanism was used on Prototype 1 as a test rig in order to assess the basic principles of the operating mechanism. This consisted of two slides carrying the supports - one from either side of the backrest as shown in fig. 70. The necessity to keep all working parts within the framework so that the backrest could lie flat, caused considerable difficulty and to enable the slides to be attached above the cross pivot bars these were 'cranked' at either side, as can be seen on fig. 70, and attached to the top frame by the wheel support castings. This 'crank' created a major problem with the strength of the cross pivot bars, as to enable bending to the required angles, and for lighter weight they were made of 16mm outside diameter aluminium tube with 1.5mm wall thickness. However, this proved to be too light and as mentioned above the 'crank' allowed a turning moment about the wheel support castings that was unacceptable. This showed clearly that the cross pivot bars would need strengthening by increasing the diameter and thickness of the tube, and eliminating the 'crank' in them. Experiments earlier had proved that it was not possible to lower the pivot points of the elevating mechanism to accommodate the backrest therefore the operation of the backrest mechanism required re-designing and development to avoid this problem.

5.6.5 As mentioned in (para.4.6.3) the carrying handles were attached to the prototype in the form of a test rig, shown in fig. 72, to evaluate the viability of using that particular position and method of folding the handles. This was shown to be unsuitable because although it offered a position with easy access to the handle ends for quick use, it obstructed movement of the legs when pushing the trolley. Earlier experiments with a test rig had shown that the carry handles could not be used in any other position on the trolley and the solution to the problem of storing the handles so that they are easily accessible yet do not cause obstruction and still provide adequate length for comfortable use was at this stage inconclusive.

5.6.6 During the development of the design to be used in Prototype 2, Prototype 1 was used as a test rig against which ideas and mock-up models could be evaluated. It was then stripped down and the basic top and lower frame used to form the structure for Prototype 2.

6 SECOND PROTOTYPE - Re-design & Final Construction

6.1 Introduction

6.1.1 The development of Prototype 2 occurred in two stages. During the first stage the functions assessed on Prototype 1 were re-designed and those functions still at design concept stage were developed into workable solutions. The second stage saw the construction of the prototype in full working order to demonstrate the principles of the operating mechanisms that are being proposed as the solution to the problems discussed during user research. Initially it was necessary to resolve the relationships between the elevating mechanism, the Trendelenberg position and the backrest as these affected the basic layout of the trolley structure. Once this had been determined it became possible to have the principal components for Prototype 2 machined whilst continuing the development of the remaining functions, however, the assembly of the trolley could not take place until all components were ready.

6.2 Re-design and further development

The major change in the structure of the trolley resulting from the assessment of Prototype 1 was the separation of the elevating mechanism and Trendelenberg operation. This involved the addition of a sub-frame to the structure to ensure that the elevating mechanism top pivots remain in a horizontal plane while the top frame separates from it at the foot end and hinges about the head end pivots to give the Trendelenberg position. This change considerably altered the concept of the design by introducing another component and requiring another separate function. The addition of the sub-frame not only increased the weight by requiring more material, but problems also arose

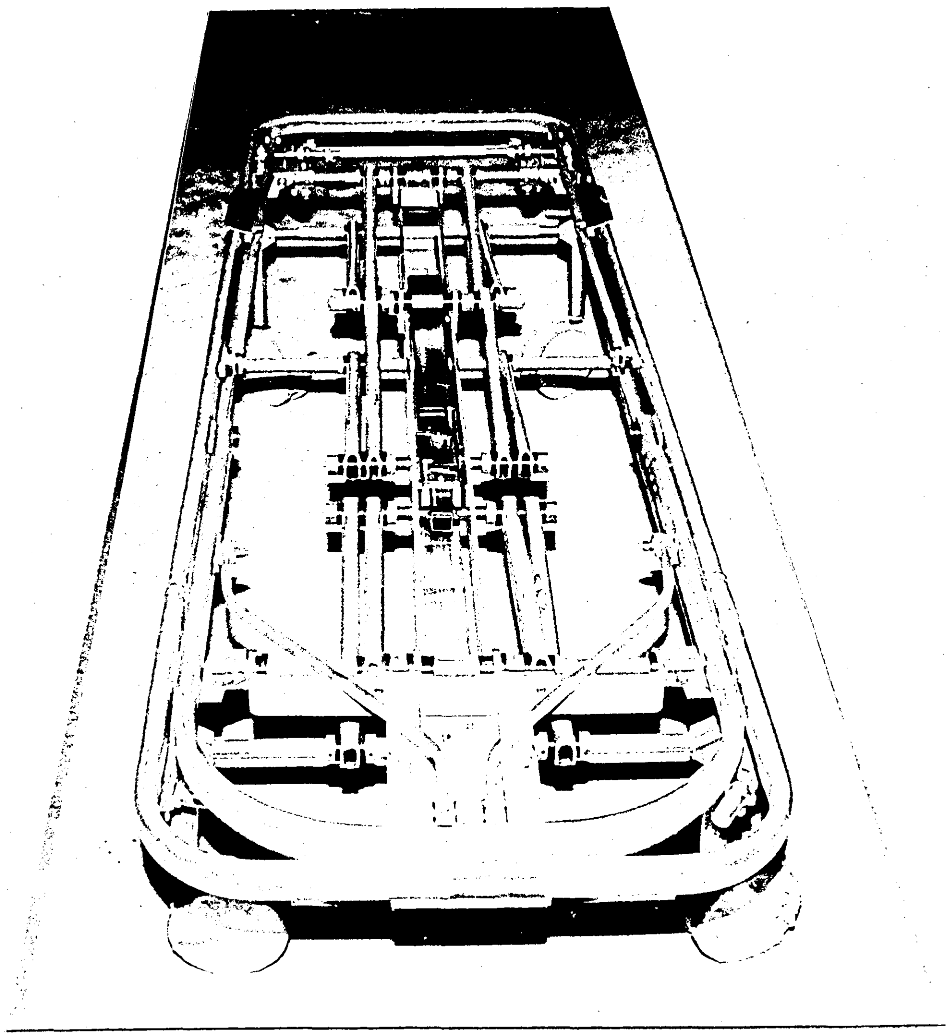
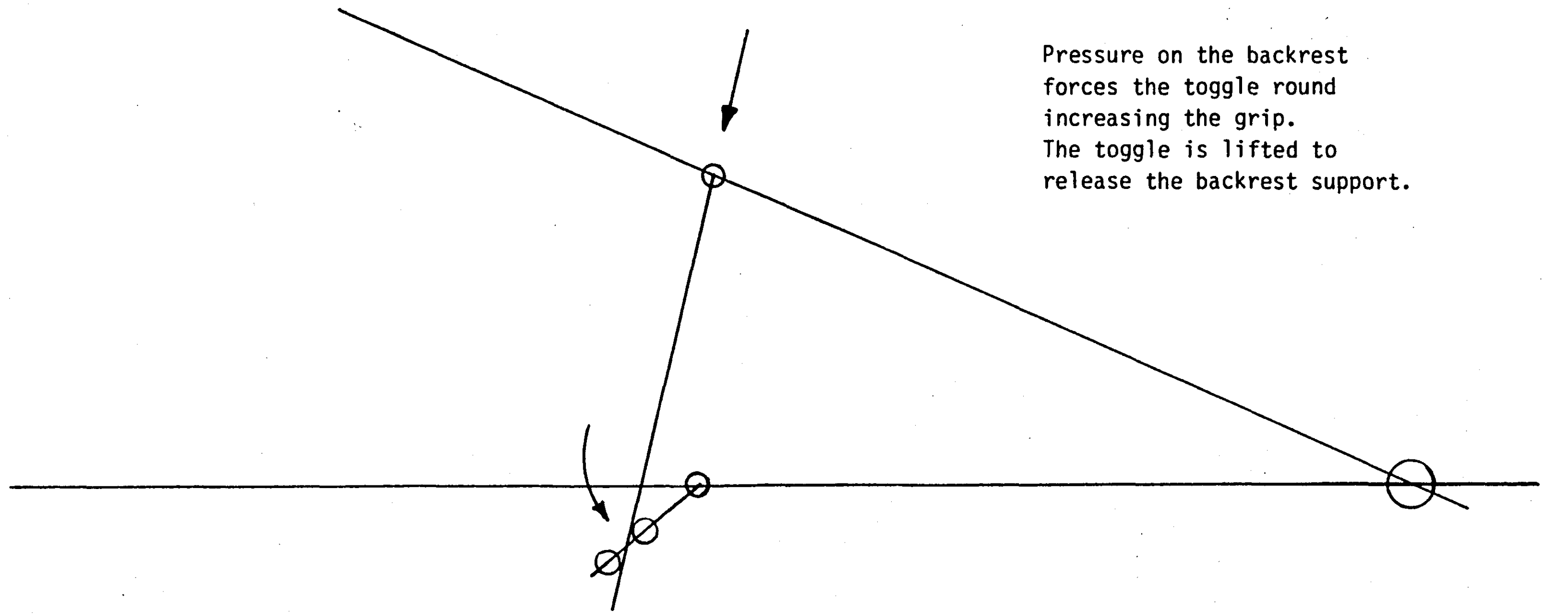


Fig. 83

Prototype 2 in the lowered position during the development period. The sub-frame can be seen on either side of the centre unit.

in relation to its position within the confined space between the top and lower frames and the central unit of the elevating mechanism. Careful adjustment was necessary to find the minimum depth of aluminium bar that would provide sufficient strength and yet fit within the space below the top surface of the top frame and the spigots for the leg pivots of the centre unit. The position of the sub-frame in relation to the width of the trolley required attention in respect to the side arms which, because of the nature of the sliding system proposed, are dependant for their height on the horizontal space available for storage between the top and lower frames across the width of the trolley. Allowances also had to be made for other mechanisms working between the top surface of the trolley and the sub-frame such as the back-rest. After careful consideration , as stated above, of the structure to be used for the sub-frame it was decided that a space of 25mm would accommodate the mechanisms for the other functions leaving a depth of 34mm for the sub-frame allowing clearances. This would enable the sub-frame to be fabricated from 31.75 x 6mm aluminium flat bar.

6.2.2 The solution to these problems used in Prototype 2 is shown in fig. 83 and consists of two long members one on either side of the centre width and spaced 55mm apart so that when the trolley is folded the members fit on either side of the central support unit and inside the leg system. Keeping the sub-frame central in the width of the trolley gave maximum space for the side arms but to give stability a cross member was fastened to the head end of the sub-frame that spans the width of the cross pivot bar between the wheel support castings. The sub-frame links the cross pivot bars together by means of lugs fitted with nylon bushings through which the pivot bars pass allowing the bars to rotate when necessary. The lugs



Pressure on the backrest
forces the toggle round
increasing the grip.
The toggle is lifted to
release the backrest support.

Fig. 84

Friction Device

project above the sub-frame to keep the pivot centres level and the sub-frame below the top surface of the trolley so that the mechanisms for the other functions, such as the backrest, could be accommodated between these two.

6.2.3 However, before the dimensions and design of the sub-frame could be finished it was felt appropriate to develop the central support unit into a satisfactory workable solution. The ideas developed during the Prototype 1 stage were reconsidered and further development was carried out on solutions that required the slide to be housed in the outer sections. A number of ways of achieving this were examined that used either a ratchet or friction locking device but none were considered satisfactory. Eventually a device was discovered in use on a hospital examination couch that seemed to offer a simple but effective solution. This relied on a gravity held friction device shown in fig. 84 which allowed an infinite number of positions along the length of the supporting rod. On consideration it was decided to develop this principle as a possible solution to the elevating mechanism lock because of its simplicity, built-in safety device and ease of manufacture.

6.2.4 As the elevating mechanism,required a horizontal central support it was necessary to design the toggle locking devices to work in this position instead of in the vertical as shown in fig. 85. Two toggle locks were used to provide locking in both directions about a central shaft which ran on nylon bearings in a square housing. This housing also contained the locks which acted about a lower pivot around the shaft. Initial tests proved that relying on a gravity or gravity-assisted friction grip would not be reliable in a horizontal position and building a working prototype confirmed this.

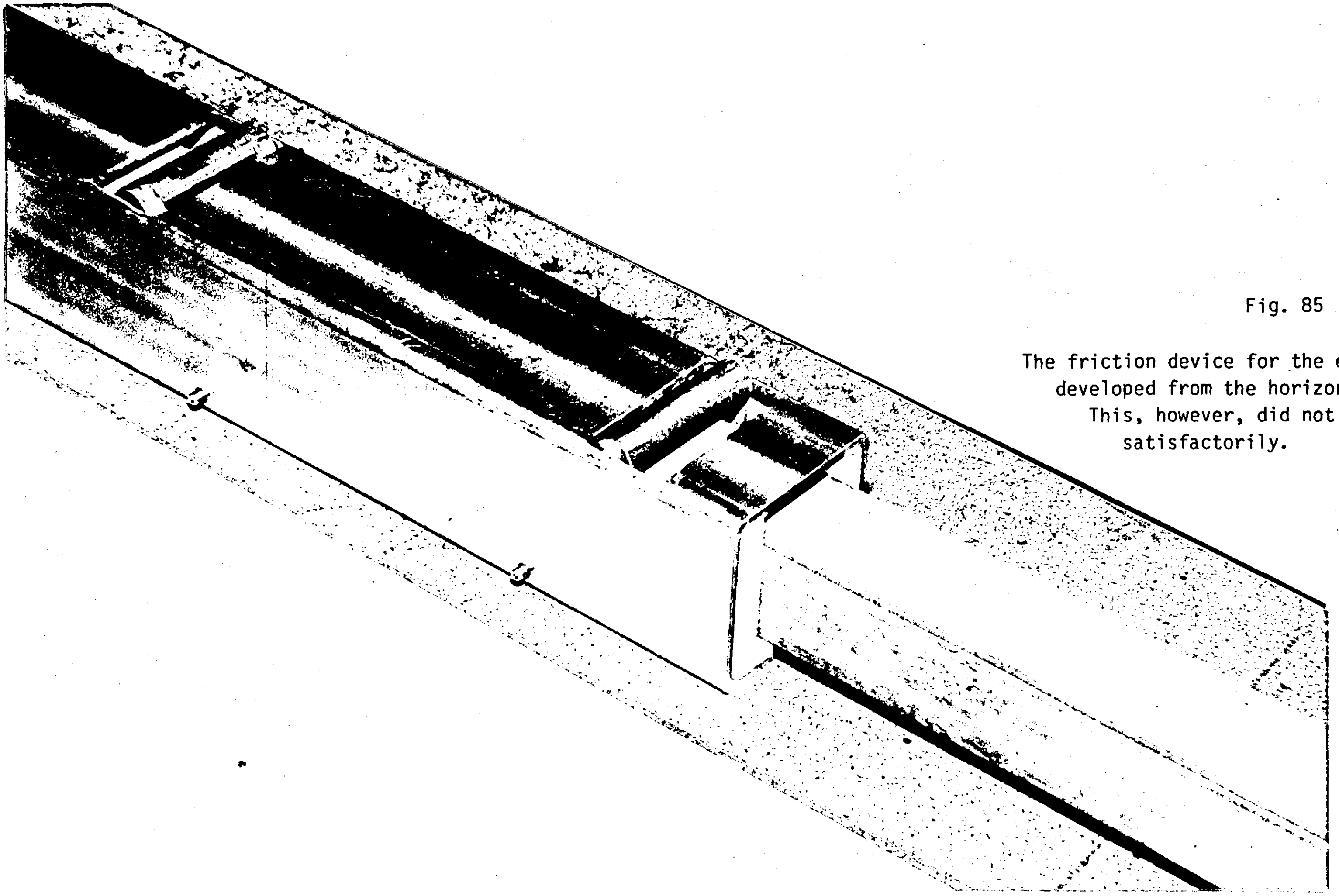


Fig. 85

The friction device for the elevating system developed from the horizontal trolley. This, however, did not work satisfactorily.

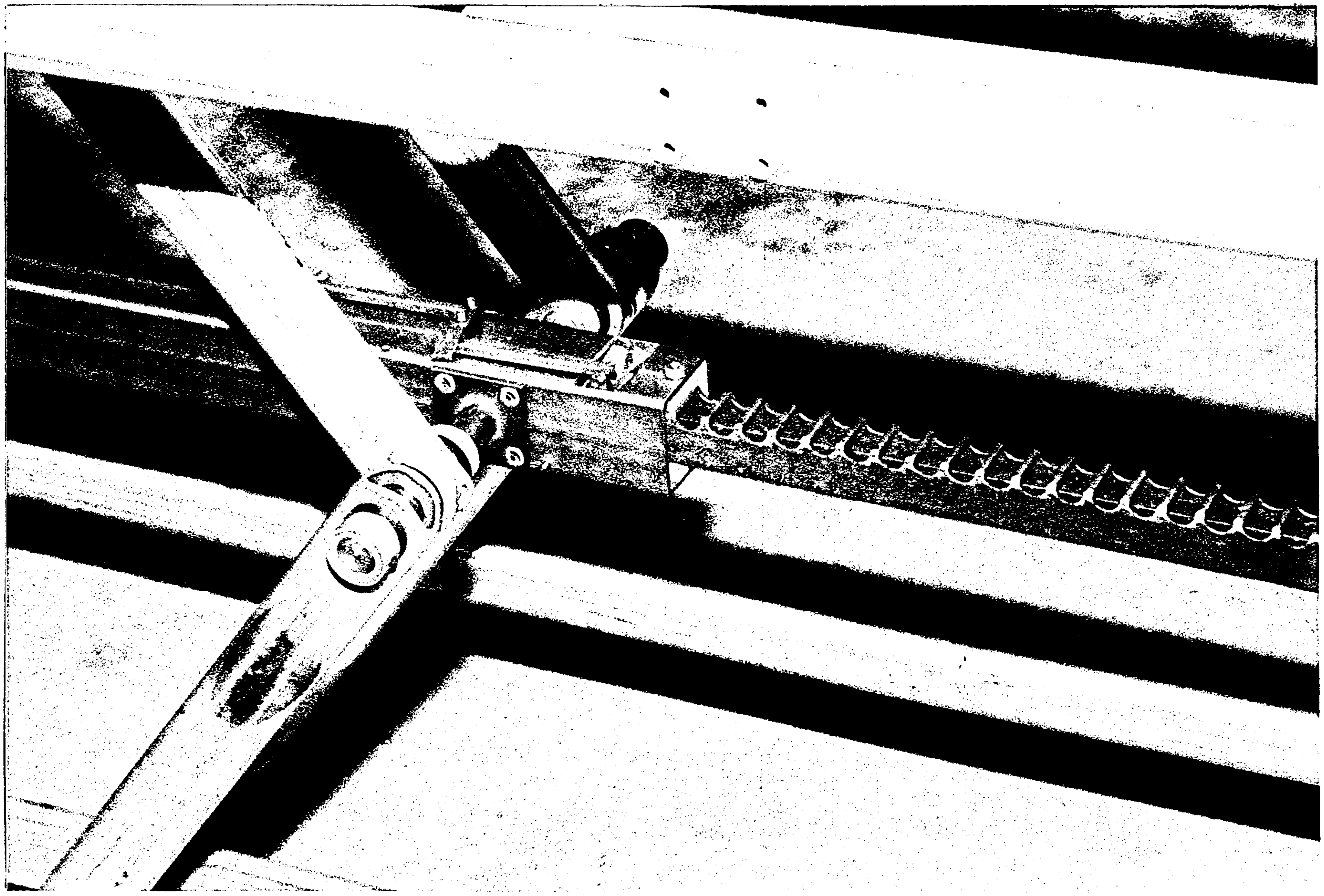


Fig. 86

The basic idea used for the friction device was converted into a neat ratchet giving positive locking action.

The problem was finally solved as shown in fig. 86 by using the central shaft as a ratchet bar with the toggle locks as the pins. The combination of a gravity-assisted dual lock ensured that the locks always fell into position if released or if the operating mechanism failed preventing complete collapse of the trolley bed. It was found that this mechanism could be housed in a 45mm x 2.31mm wall thickness square section with a 25mm square ratchet bar working in it. The pivot spigots for the leg units were attahced with the double parallel units on the outer housing and the single leg unit at the outer end of the inner ratchet bar, and as for the prototype, steel section was used these were fastened by welding. This device offered a neat solution to the problem of locking the elevating mechanism but the problem still remained to devise a means of releasing the locks when required. The user research showed that although it would be preferable to use only one position when elevating the trolley, that being the side loading position, it was still necessary to provide both the side and end loading positions. This meant that the release device required operation from at least two positions and ideally any operating lever or handle should be situated on the top frame at the appropriate hand position for lifting. It was felt that a system of mechanical levers for releasing the toggles would be complicated and difficult to locate in the limited space available and adjust to the varying heights, therefore, a cable from the toggles to the operating device seemed to offer the most flexible and uncomplicated solution. At the central support a release system was attached to the toggles as shown in fig. 86 which operated both toggles simultaneously and their return was ensured by the use of a spring. Initially a single cable was attached to this and taken up the centre

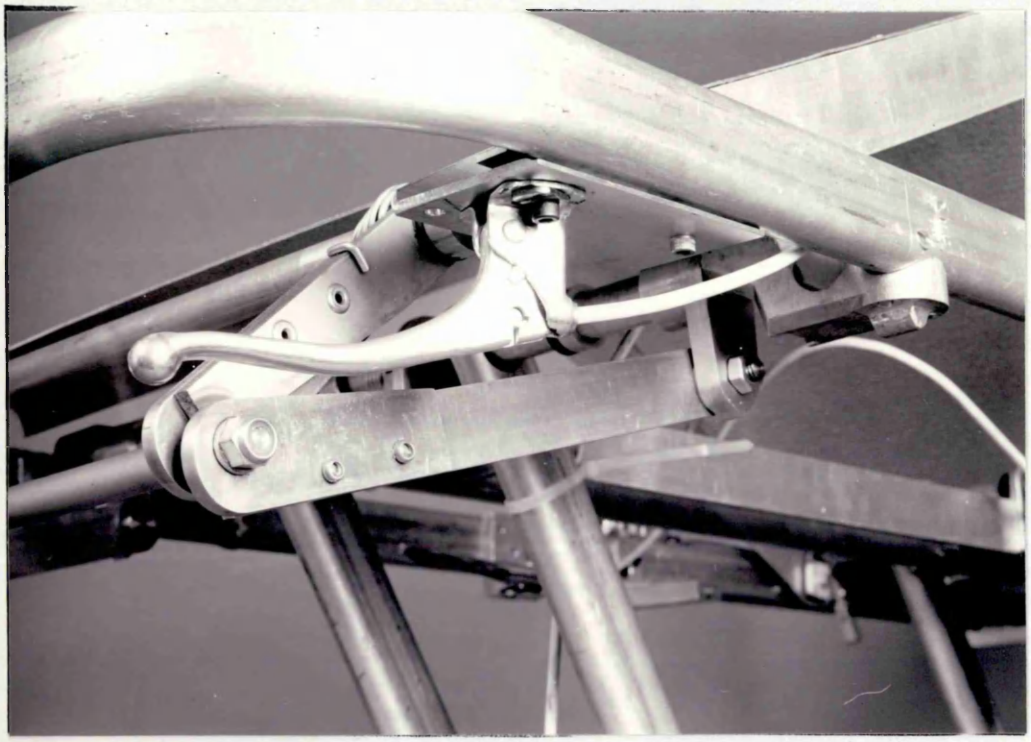


Fig. 87

The release lever for the elevating mechanism at the foot end of the trolley on the final version of Prototype 2.

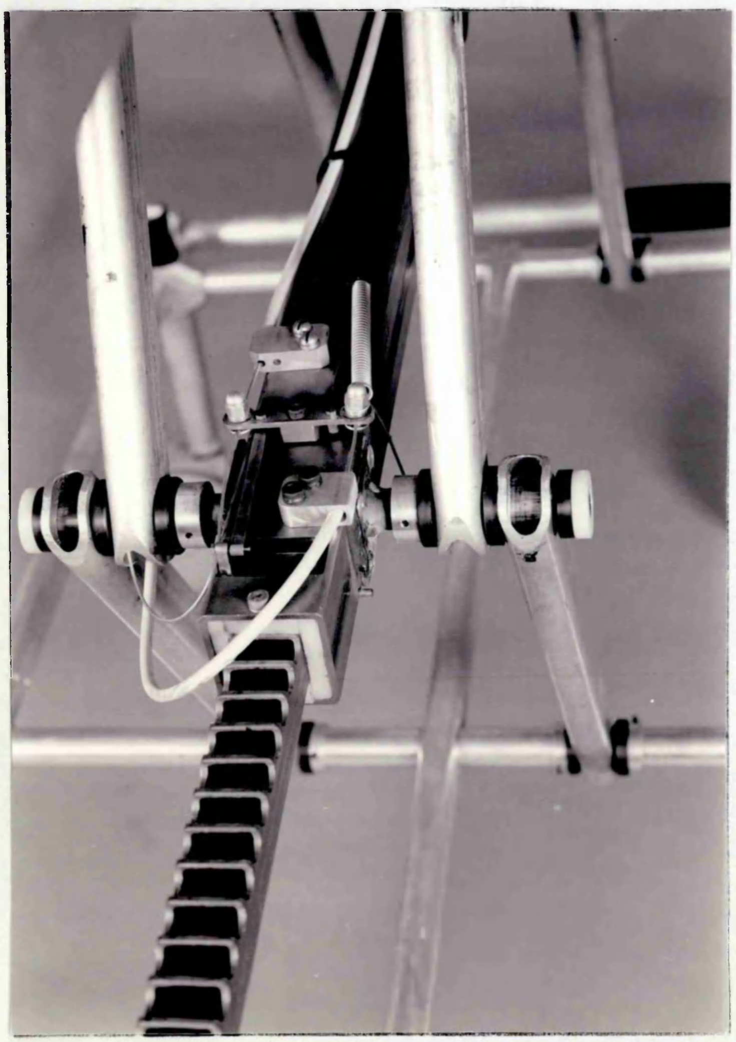


Fig. 88

The release/lock mechanism finally developed for Prototype 2 showing the cable attachment to the kevers on the top frame.

leg where it was attached to a 'Bowden' cable around the inside of the top frame and running from the backrest pivot on one side round the foot end of the trolley and to the opposite backrest pivot. However, this, though it would have enabled operating from anywhere around the trolley foot end, proved unreliable because the stretch in the cable was greater than the movement required to release the toggles. It was then decided to use two levers situated one at the foot end of the trolley as shown in fig. 87 and the other on one side attached to the inside of the top frame, and to use two individual cables from these to the central support unit. Fig. 88 shows the control release mechanism in use on the finished Prototype 2.

6.2.5 During the development of the sub-frame and elevating mechanism further ideas to achieve the Fowler's position were explored. As the various screw thread solutions had been rejected as unsatisfactory it was decided to examine other ways of achieving this position by working back to first principles. The purpose of the Fowler's position is to elevate the knees to relieve strain of the abdominal muscles, and a normal method of achieving this would be to lift the casualty's knees up by placing an arm beneath them. This, however, can be embarrassing to the casualty but it seemed possible to lift the appropriate section of the trolley bed under the knees instead so maintaining dignity and avoiding embarrassment to the casualty, but to achieve this some way of locking the sections when raised had to be found. Various methods of doing this had already been discarded because of the problem of projecting levers extending below the trolley frame but it appeared possible to maintain this position by using a toggle lever at the foot end of the section with stops that prevented

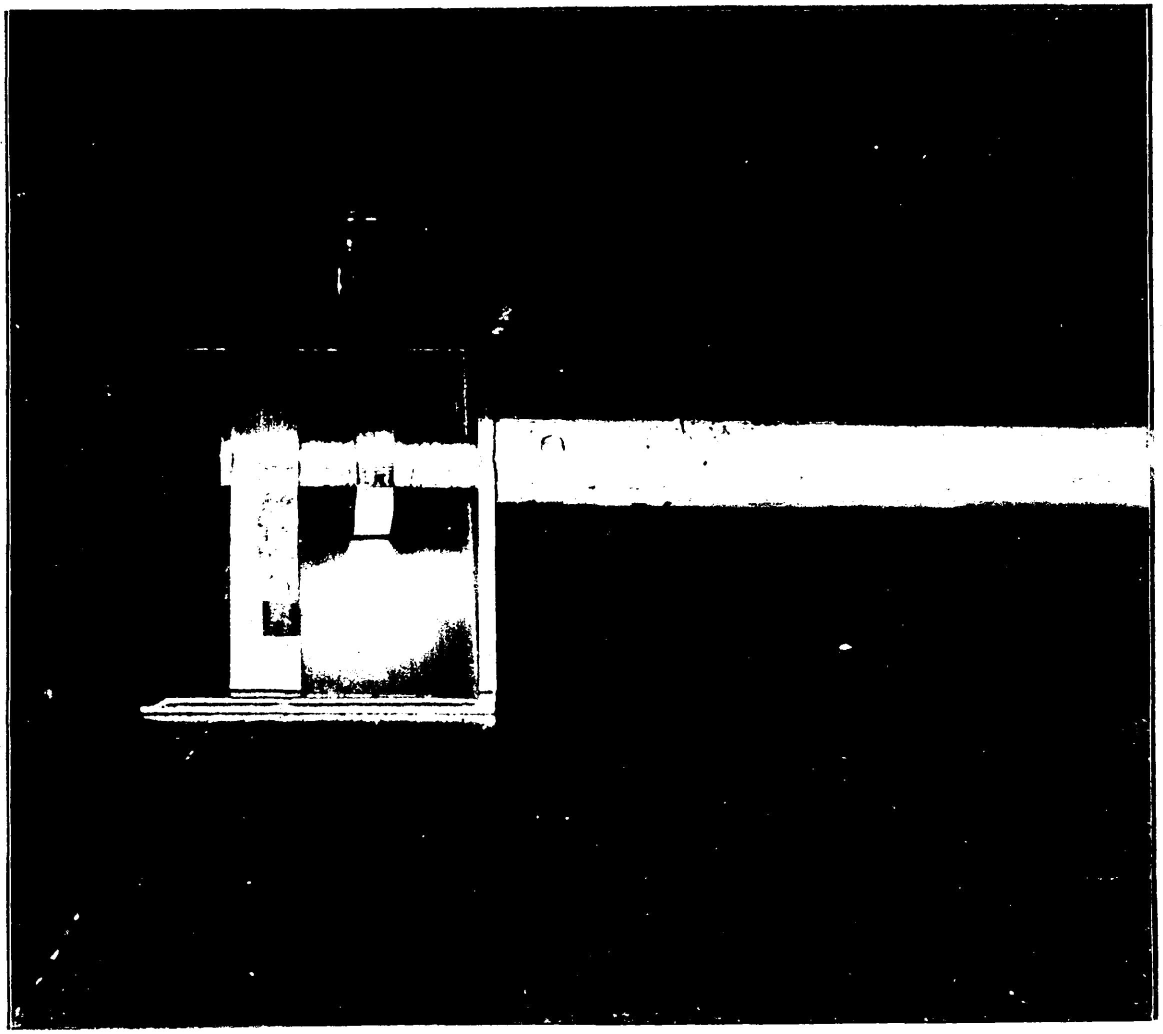


Fig. 89

The toggle mechanism for the Fowler's position with the cross bar and side brackets shown during the development of Prototype 2.

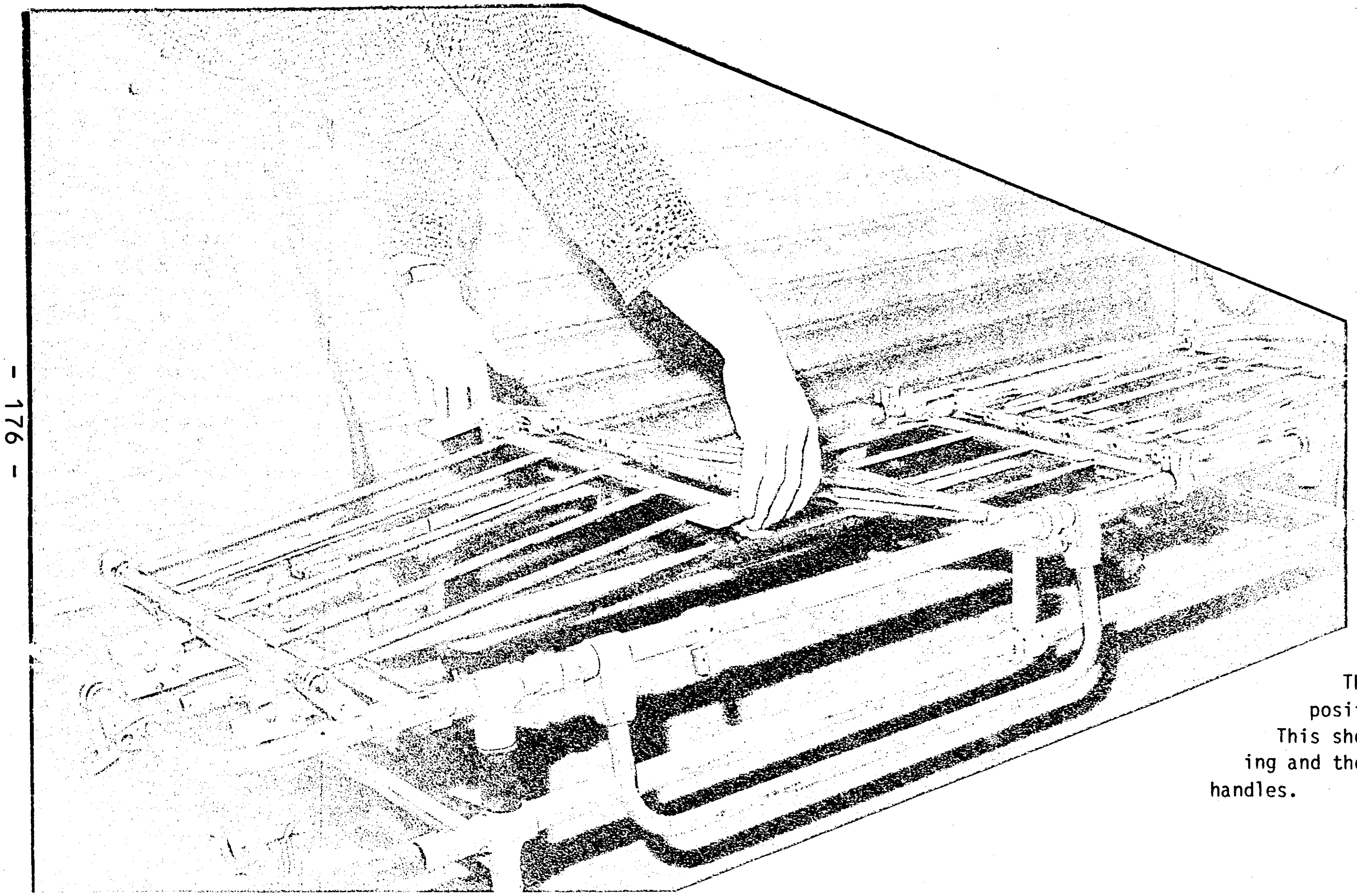


Fig. 90

The development of the Fowler's position mechanism on an old trolley. This shows the mechanism during lifting and the position of the hands on the handles.

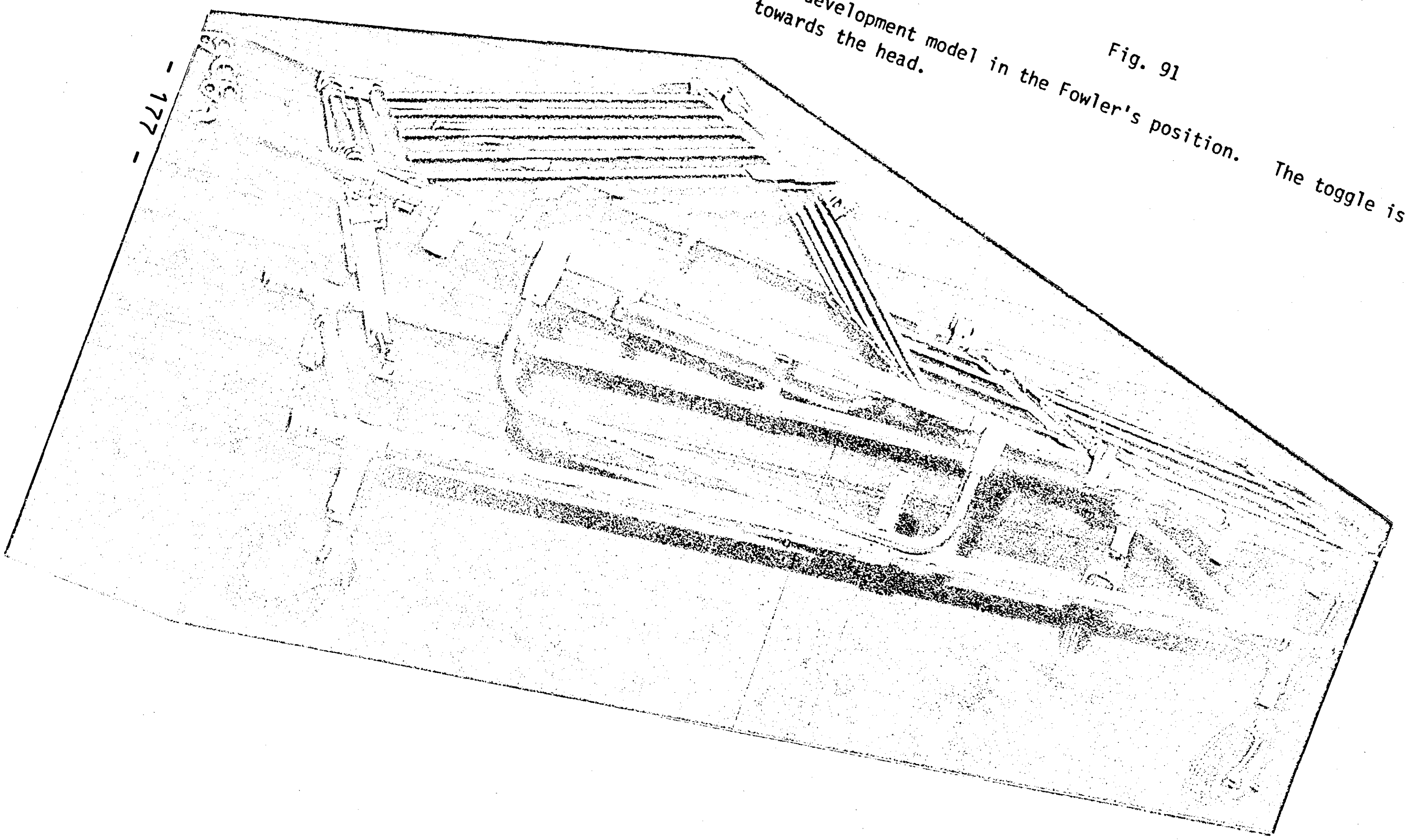


Fig. 91

The development model in the Fowler's position. The toggle is pointing towards the head.

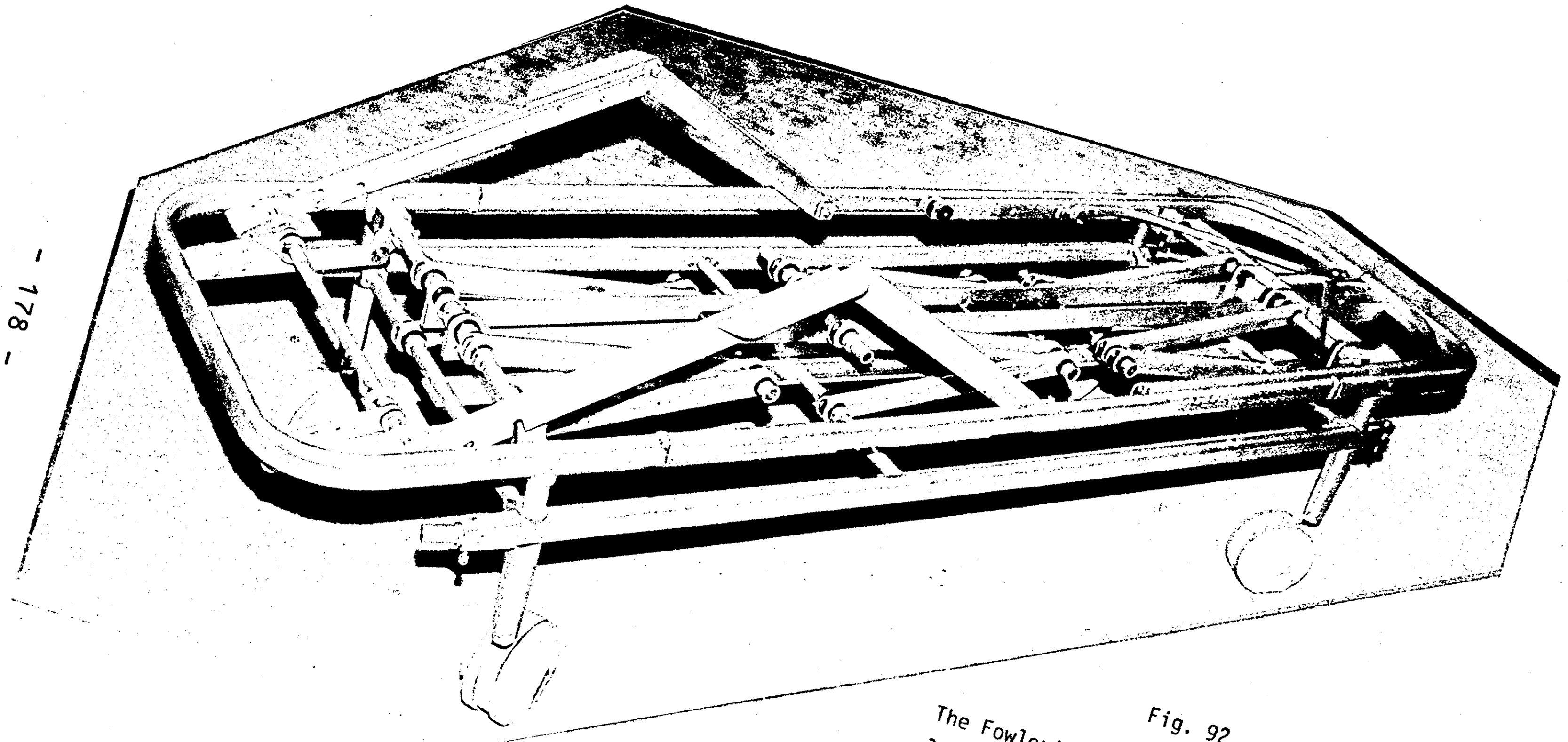


Fig. 92

The Fowler's position was then developed as shown on Prototype 2.

more than 180° movement as shown in fig. 89, then when the toggle lever points towards the foot of the trolley the bed lies flat but as the centre hinge between the two sections is lifted as shown in fig. 90 the toggle lever swings over to point towards the head and the section remains in a raised position, as seen in fig. 91. This was developed as a test rig on an old existing trolley frame as can be seen from figs. 90 and 91 and the details of the lifting handle position and operation of the toggle lever further developed for inclusion in Prototype 2 as shown in fig. 92.

6.2.6 After development of the Fowler's position the Trendelenberg position was considered in the context of the use of a sub-frame. This indicated that support to maintain this position would be required at the foot end of the trolley working between the sub-frame and the top frame. A height of 296.2mm vertically from the pivot point was required to give the recommended 12.5° of tilt but the operating mechanism would be required to fold down within the space between the top frame and the foot end pivot bar. Experiments with a full scale drawing, taking one end of the supports to be the foot end pivot bar attached to the sub-frame and the other to be the cross bar supporting the Fowler's position toggle lever on the top frame, showed that this would only be possible by using a two section bar with the short section attached to the top frame and no more than 120mm long so that when flat it fitted between the cross bar and the inside of the end of the top frame. The length of the lower section needed to be 230mm so that when extended the two together in a straight line gave the required 350mm length to maintain the 12.5° of tilt, as shown in figs. 93 and 94, then when folded the support will fit between the hinge with the top section and the cross pivot bar

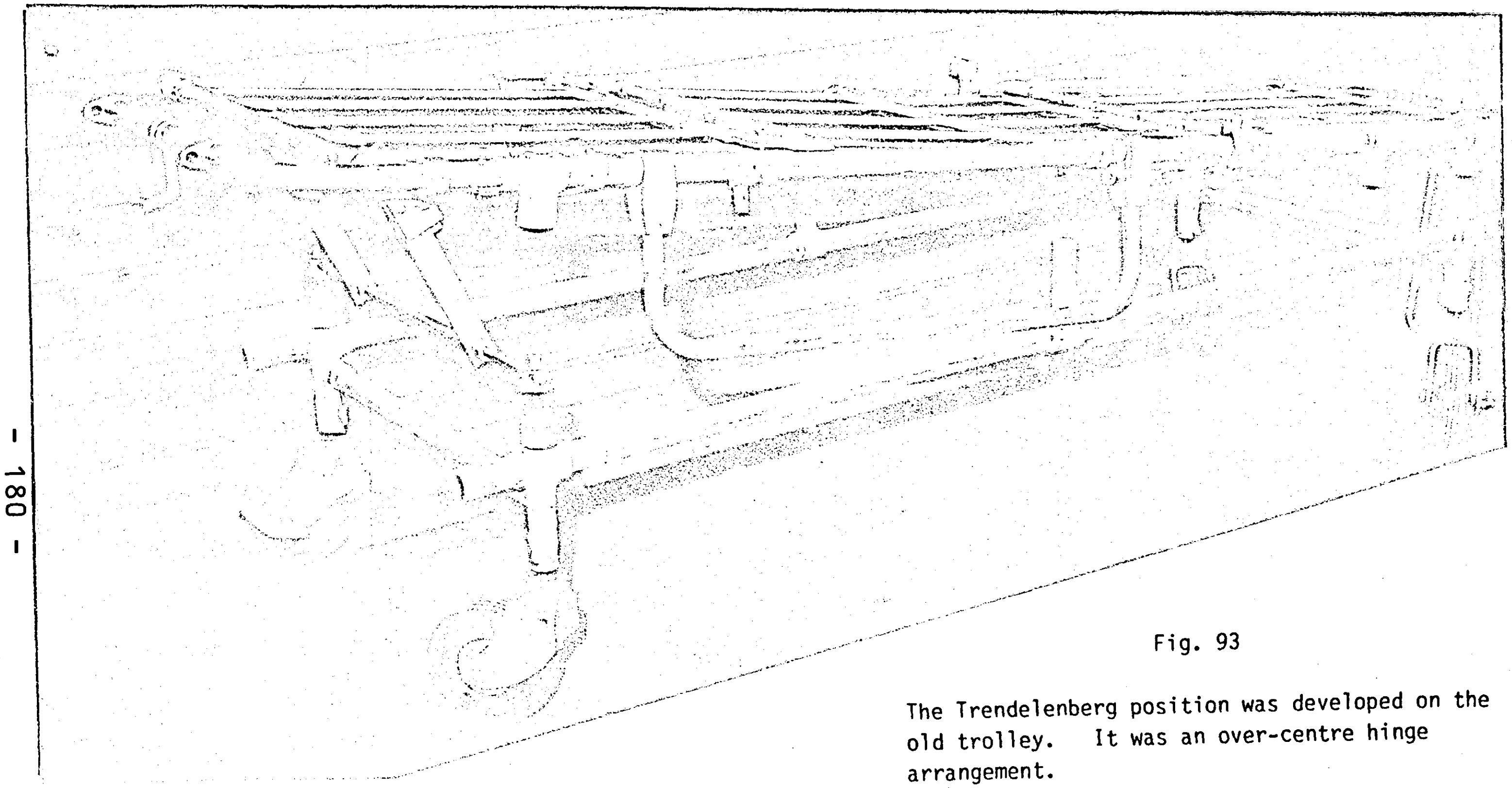


Fig. 93

The Trendelenberg position was developed on the old trolley.   It was an over-centre hinge arrangement.

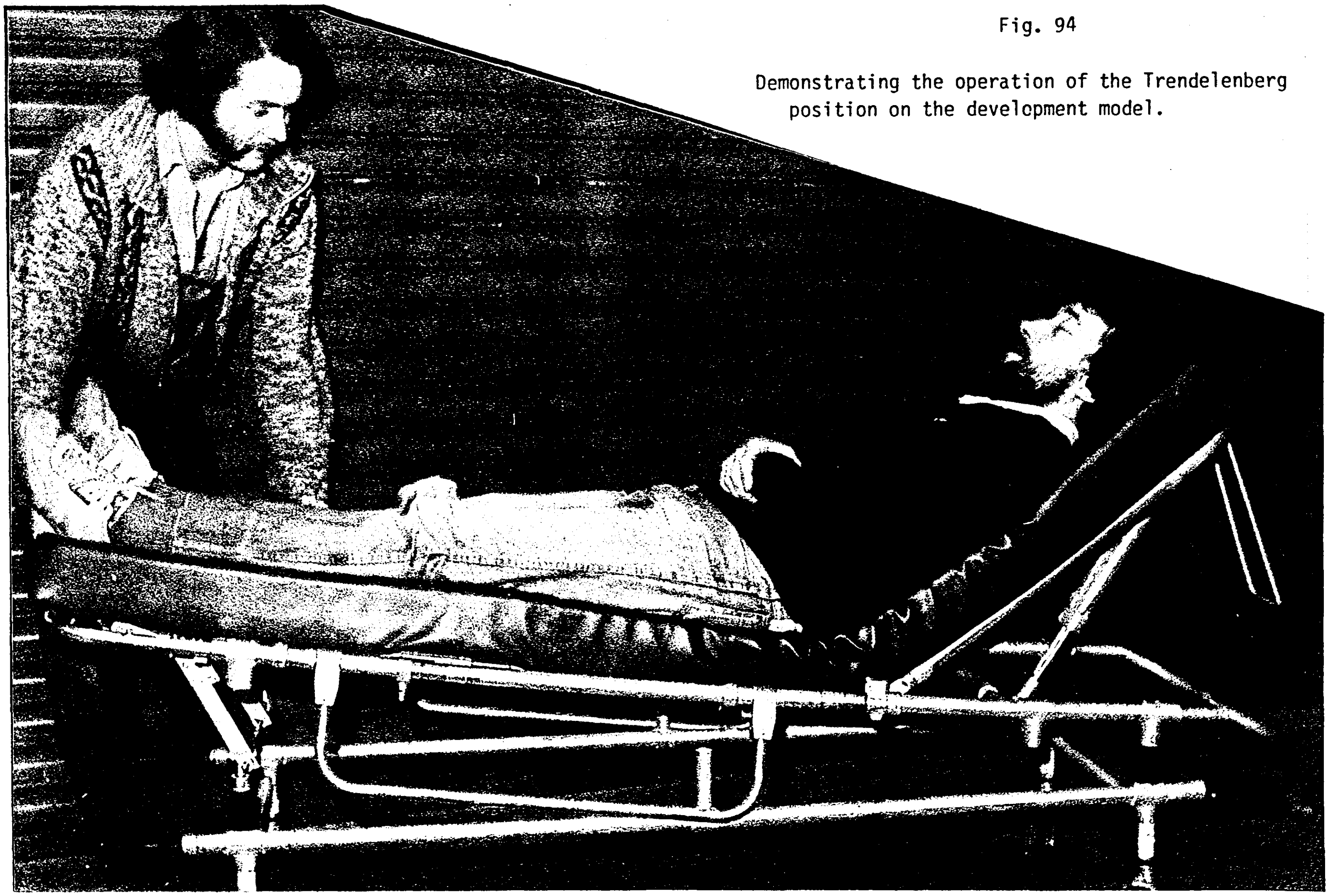


Fig. 94

Demonstrating the operation of the Trendelenberg position on the development model.

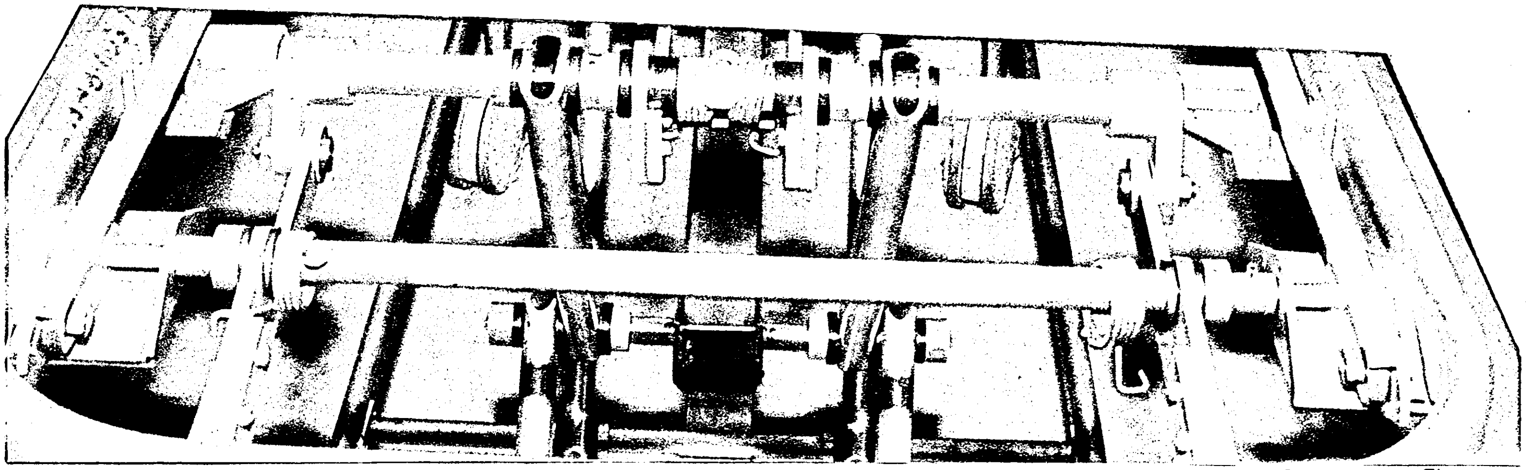


Fig. 95

This shows Prototype 2 with the Trendelenberg device folded during development. The springs that will snap the over centre hinges into position can be seen on the cross pivot bar to which the Fowler's position is attached.

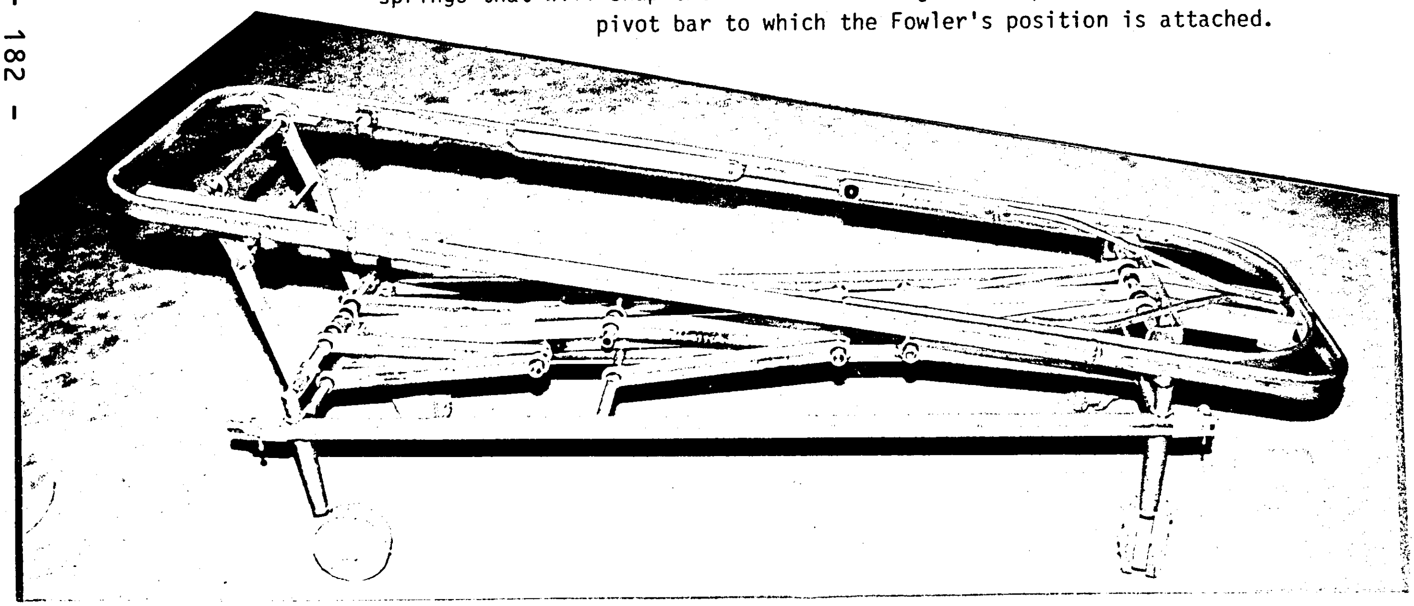


Fig. 96

Prototype 2 in the Trendelenberg position.

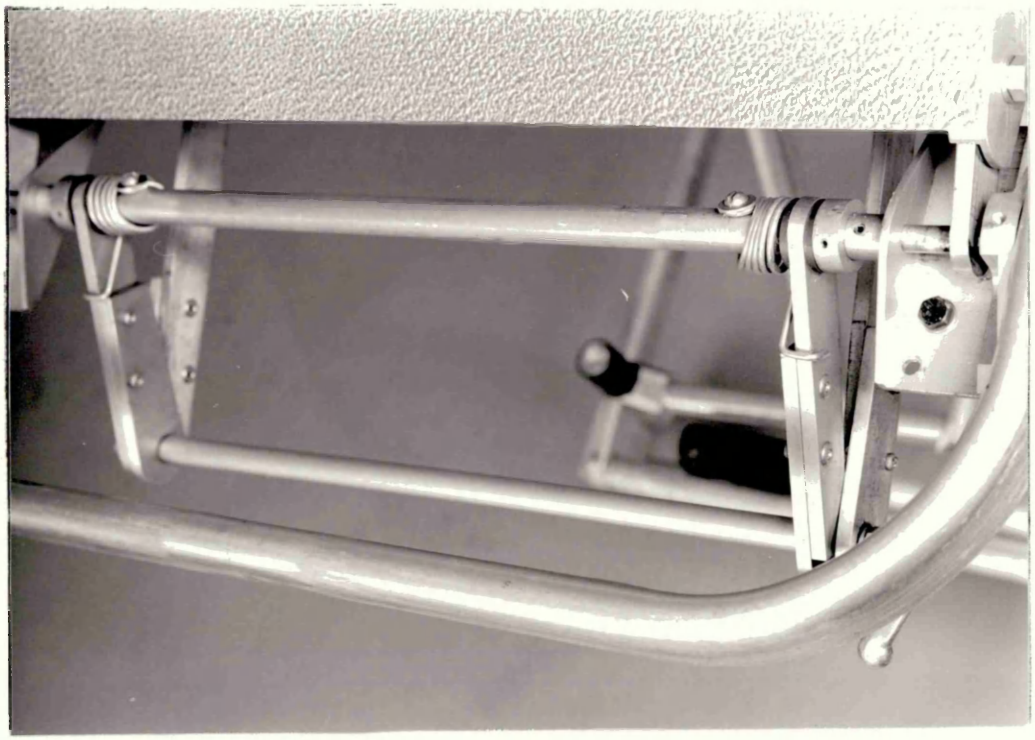


Fig. 97

This shows the operating device for the Trendelenberg position on the final version of Prototype 2. The bar between the hinge acts as the operating lever for this feature.

on the sub-frame as shown in fig. 95. This was also built to test rig stage on the old existing trolley and experiments with springs showed that the addition of two torsion springs to the top sections made the hinge snap into position when straight as shown in fig. 96 and this was strengthened by using an over centre hinge arrangement.

6.2.7 This operation was further developed and detailed for Prototype 2. A locking system was needed to prevent the top frame leaving the sub-frame on lifting when not requiring the Trendelenberg position. It seemed unwieldly to have a separate lock that would require another operation to release it so ways were examined to incorporate the lock into the mechanism. This was finally achieved using the layout shown in fig. 95, by locating a pin in the wheel support casting in a slot in the solid end of the cross pivot bar, which are not visible in the photograph. When rotated the slot in the cross pivot bar turns away from the pin and releases the wheel support casting allowing the top frame to rise. Rotation of the cross pivot bar is obtained by pushing downwards on the bar connecting the two hinges on the support bars, as shown in fig. 97. The supports are spring loaded and snap out straight as mentioned earlier and shown in fig. 96.

6.2.8 The re-design of the elevating system and the addition of the sub-frame eliminated the 'cranked' ends to the cross pivot bars which are now straight. This required a re-design of the wheel support castings as the pivot fastening points on the top frame are now central instead of below the frame. This gave the opportunity to re-think the aesthetics of these castings in relation to the different section shapes that are connected to them especially as it had been decided from

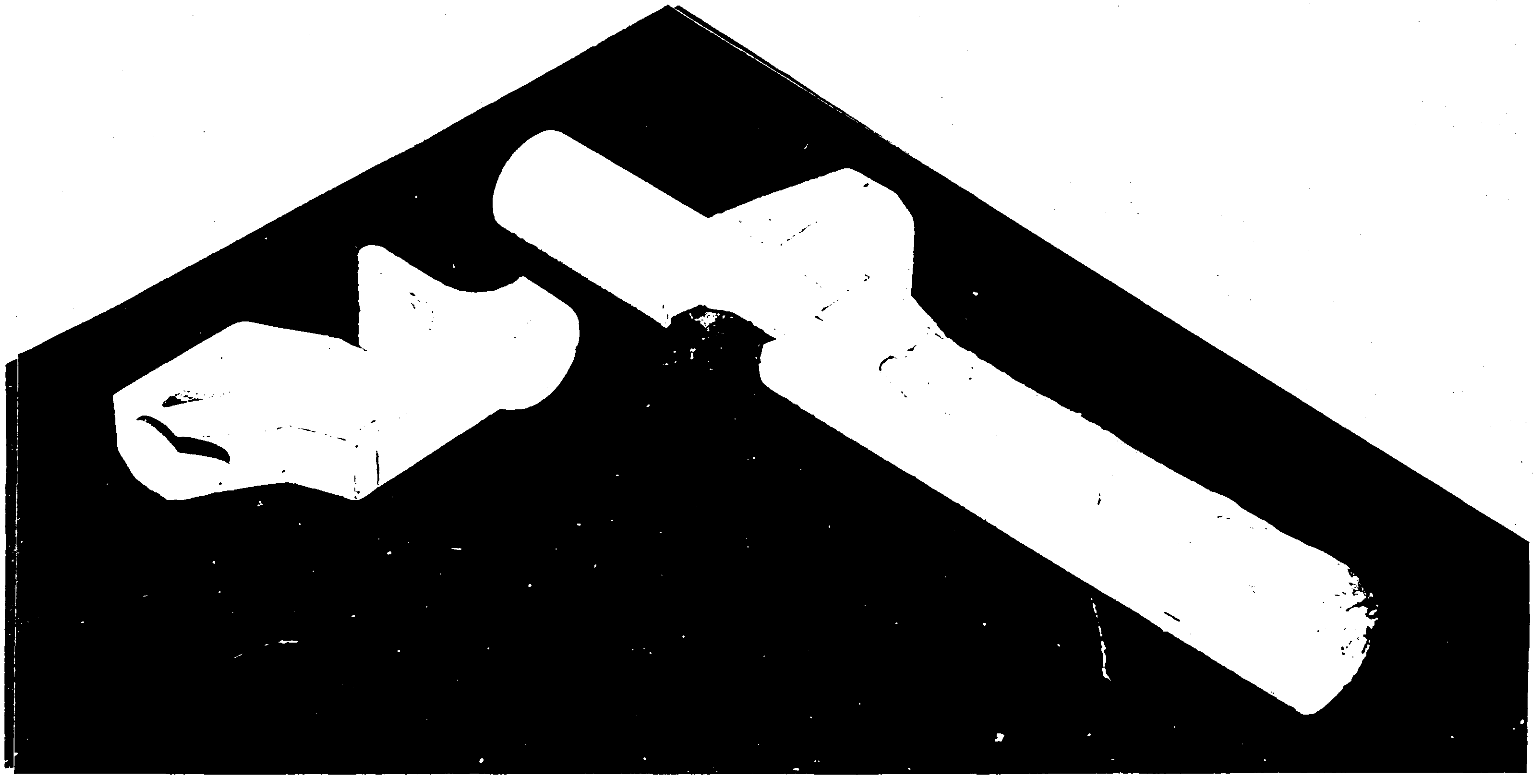


Fig. 98

The wheel unit casting was first developed as a wooden model.

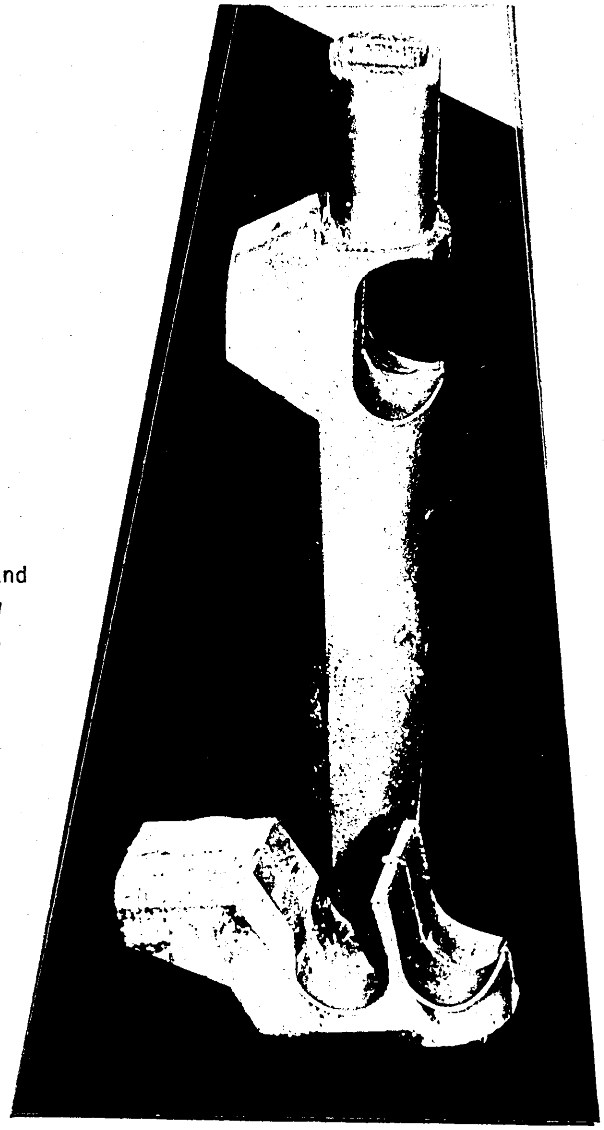


Fig. 99

The wheel units were produced as sand castings for Prototype 2 - end view showing the oval cut out which fits around the lever frame.

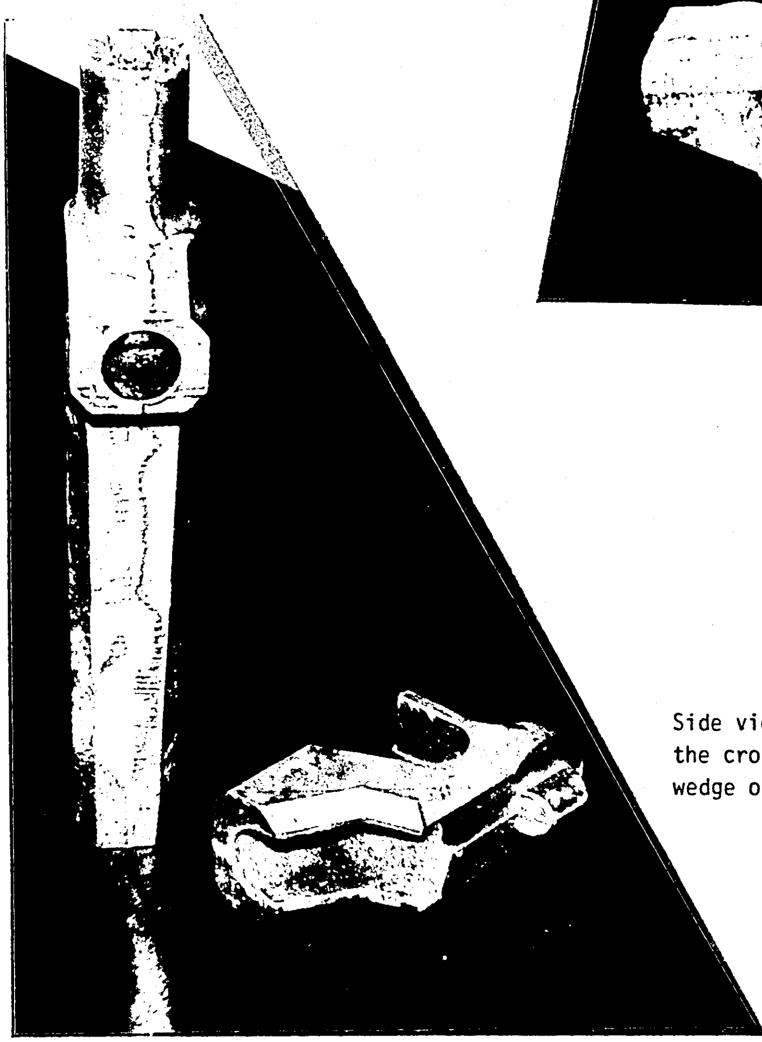


Fig. 100

Side view showing the position of the cross pivot bars and the locating wedge on the top unit.

Prototype 1 that the section providing the lock in the ambulance needs to be circular and of 32mm diameter for the locks to be effective. This lock section needs to be part of the lower casting to prevent its pulling out of the lock should the trolley jump when the ambulance is travelling. On examining these units on Prototype 1 it was decided to relate the rather square shape of these to the circular section required for the lock and a wooden model was made which was adjusted to give the final shape required as shown in fig. 98. This incorporated a semi-circular section which was chamfered into a straight side and on the lower casting tapered to the wheel unit. Some reduction in materials was made by removing the material outside the top and lower frames where the castings were made to fit around the flat oval shape and fasten to the frame by means of screws, through both casting and inner frame wall, located in the holes provided to take the cross pivot bars. Although the outer diameter of the locking section is 32mm the casting was made with a 25mm diameter section and the outer diameter is provided by the addition of a polyethylene collar which cushions the locking unit and prevents rattling noise. These were produced as sand castings as shown in figs. 99 and 100 for Prototype 2.

6.2.9 During the design of the above features the backrest was also considered, as provision had to be made for this in the design of the top wheel support castings and in the dimensioning of the sub-frame. The backrest frame was not changed from that used in Prototype 1 except that it was decided after examining the ergonomic data according to Dreyfuss (20), to lengthen the backrest frame from 650mm to 725mm to accommodate the length of back for a man of average height. The neck position for the hyper-extension feature is

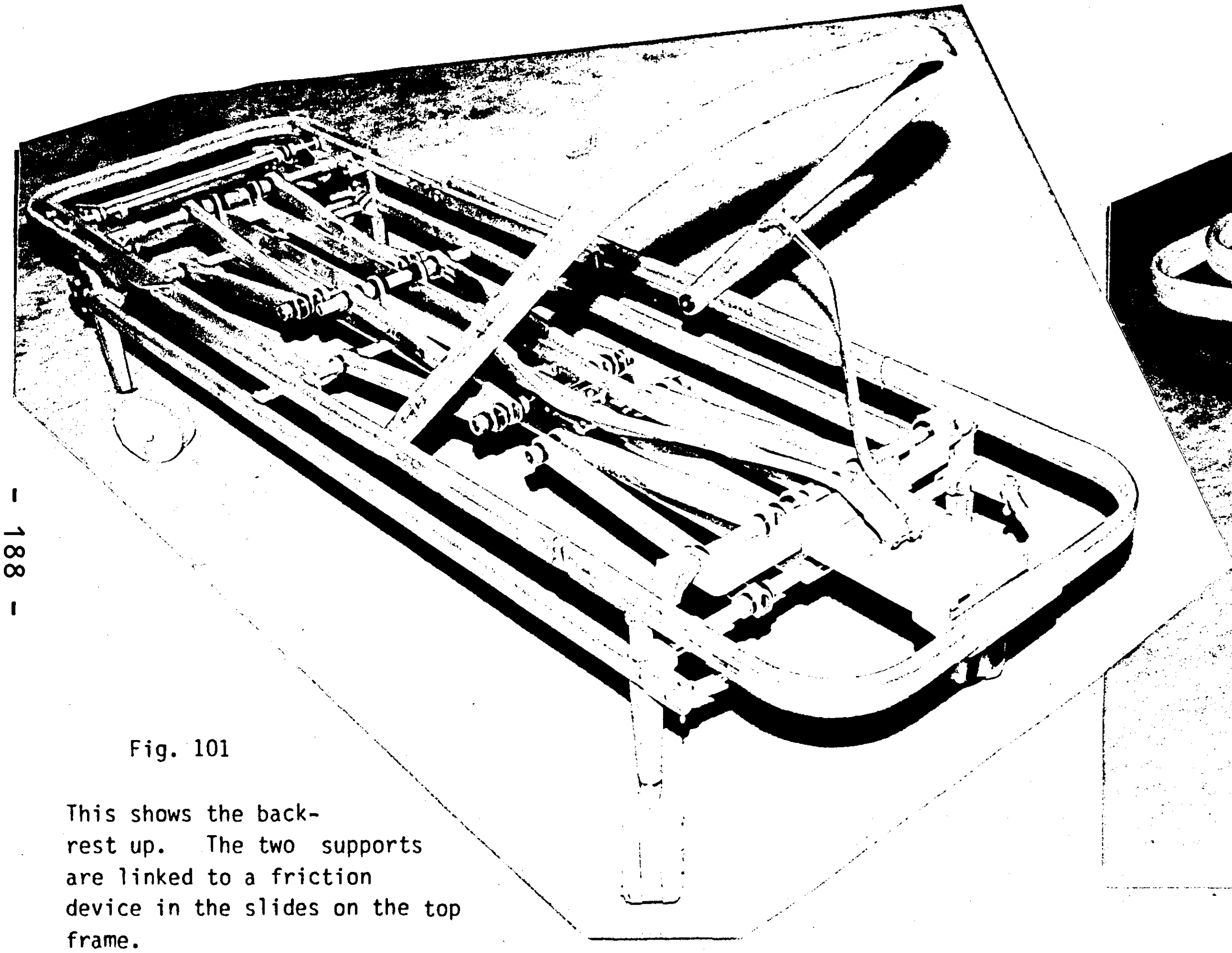


Fig. 101

This shows the back-
rest up. The two supports
are linked to a friction
device in the slides on the top
frame.

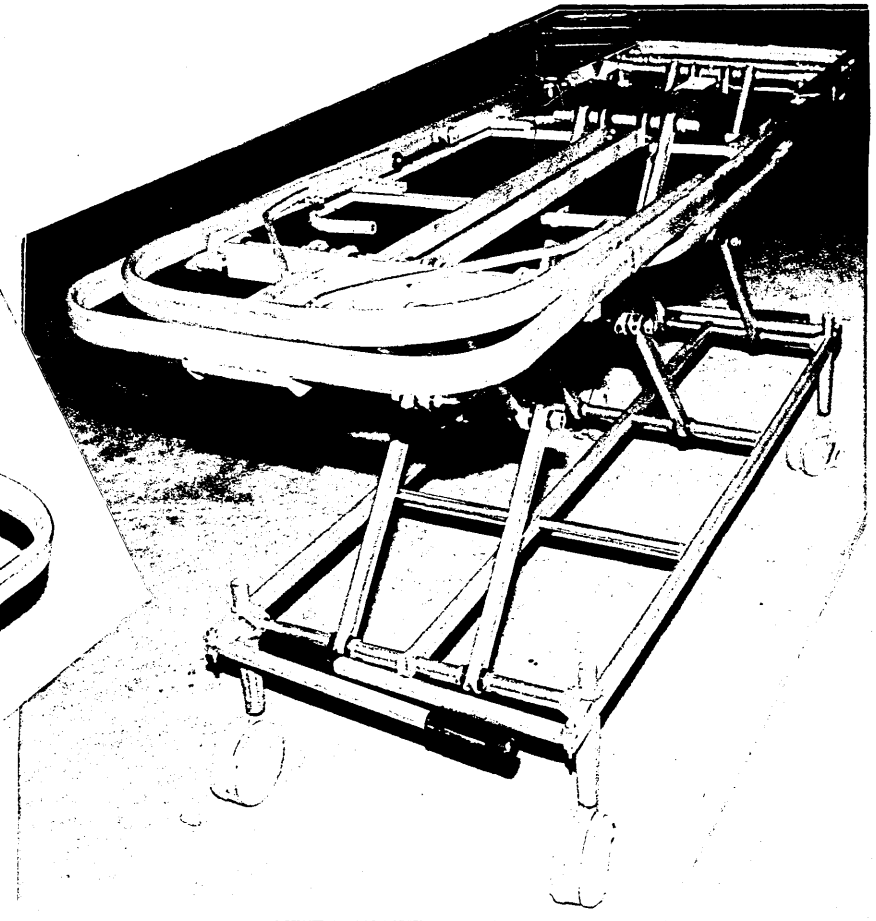


Fig. 102

Prototype 2 during development with the backrest down.

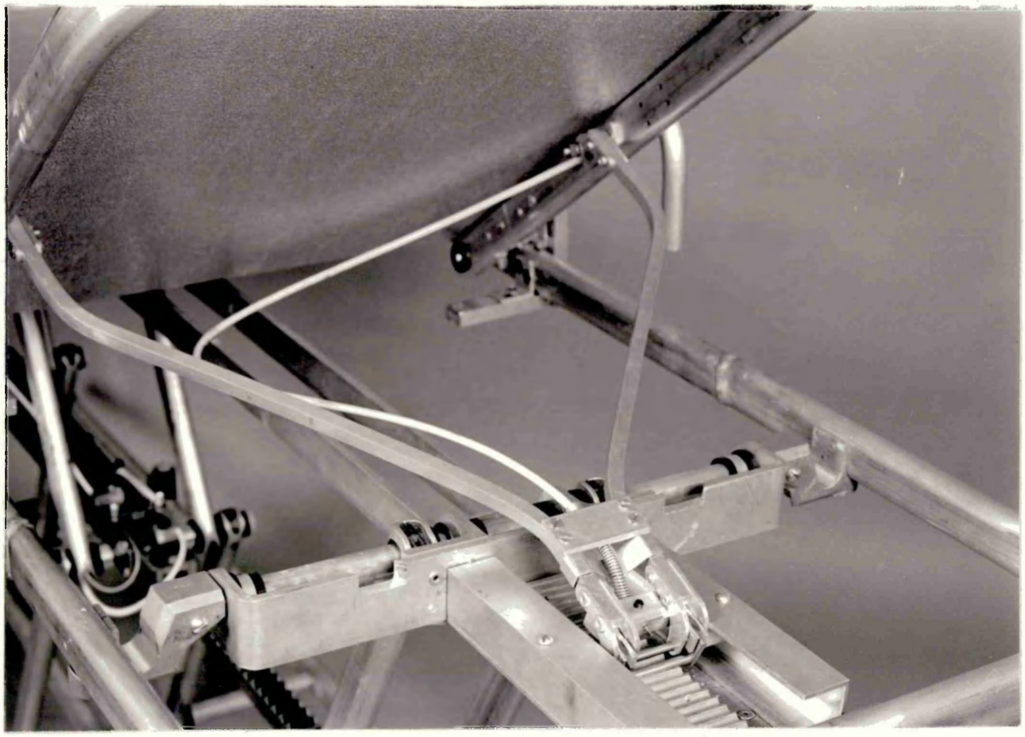


Fig. 103

The friction device was changed to a more positive ratchet system operated by a cable release to a handle inside the top of the backrest.

a fixed distance that will accommodate all head sizes from the head end of the trolley, and it was felt that it would be easier to adjust persons to this position as the fixed distance ensures that the head will be protected by the mattress when tilted back but that the new length of backrest will accommodate a larger user range then before.

6.2.10 With the removal of the cranked pivot bars as mentioned above it became essential to examine other methods of operating and locking the backrest that would be capable of working within the confined space between the top surface of the trolley and the sub-frame. It was still felt preferable that the operating mechanism should be kept horizontal between the backrest pivot and the head end of the top frame with the pivot and the supporting bars attached to the backrest. Full size drawings were used to determine the dimensions that would enable the supporting bars to be folded into the limited space available and it was decided that with some adjustment to the shape of the support bars the operating mechanism and lock would work between the sub-frame and the inside of the head end of the trolley as shown in figs. 101 and 102. It became necessary then to design a locking and releasing system that would work within the space of 203mm length and 40mm depth and be capable of operation from the head end of the backrest frame. This precluded some form of cable operated mechanism, and a cam-type friction device was developed that comprised two cams that worked within a channel and relied on the weight on the backrest to rotate them about an axle to the locked position. Lifting the backrest released them and allowed it to be raised. However, on testing these were found to slip too easily and the backrest would fall, therefore, another device had to be developed. This worked in the same position as the previous one but consists of a ratchet plate with a bar acting around a pivot which allows it to fall into place and lock as shown in fig. 103. A cam action on the lugs attached to the bar ensured that the weight on the backrest kept the bar in the locked position but once the backrest was lifted then the bar was free to move to another position. The supports were attached to the sides of the backrest and bent in as shown in fig. 102 so that the ends attached to the ratchet bar in the centre were parallel to each other and the correct distance apart. The mechanism is released by a spring-loaded cable shown in fig. 103, that ensures the return of the ratchet bar to the locked position. The cable is taken out to the head end of the backrest where it is attached to an operating lever inside the left corner of the frame and access to this lever is through the gap left between the corner radii of the top frame and that of the backrest. This ensures that there is no danger of trapping fingers or hands when releasing the backrest with a weight on.

6.2.11 While designing the backrest it was appropriate to consider the hyper-extension facility as this would need to be incorporated either into the back-rest or be applied by some external means such as an added wedge shape that could be placed under the neck. Various mechanical means of achieving this position in the backrest were proposed but all were complicated and would have required the addition of joints which would weaken the frame. As none of these ideas were satisfactory it was decided to examine the basic principles of using this position and derive ideas from this. At present this position is maintained by placing a rolled blanket under the casualty's neck but it seemed unsuitable to propose the use of a wedge

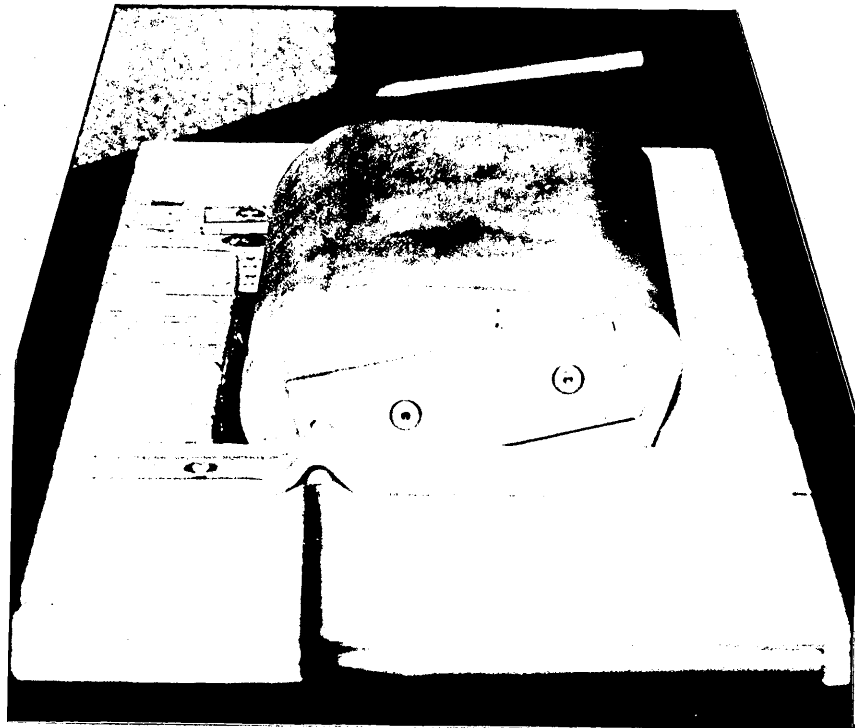


Fig. 104

The first development model for the hyper-extension feature was a wooden cam shaped to lie flat within the mattress.,

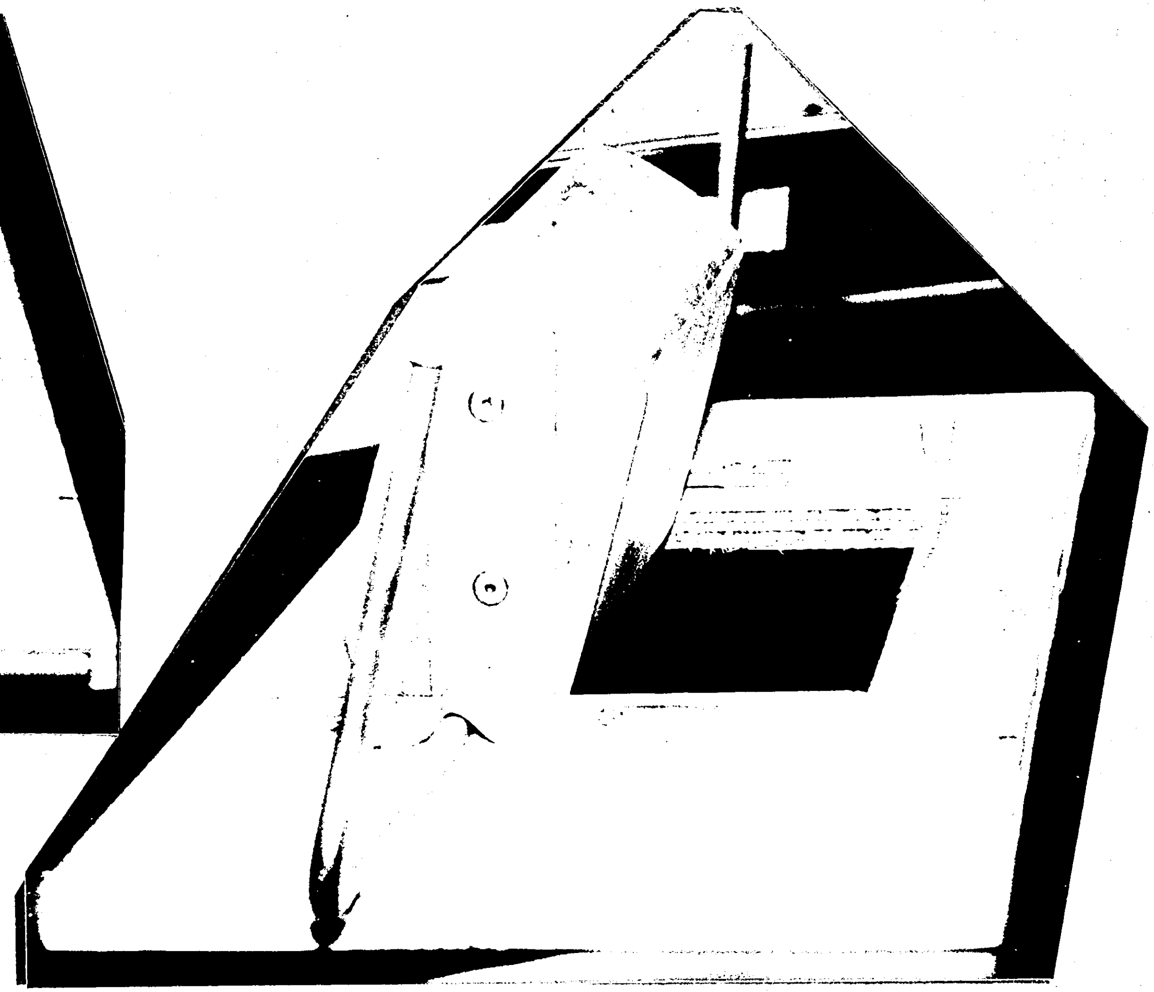


Fig. 105

.. and to fit the back of the neck when raised.

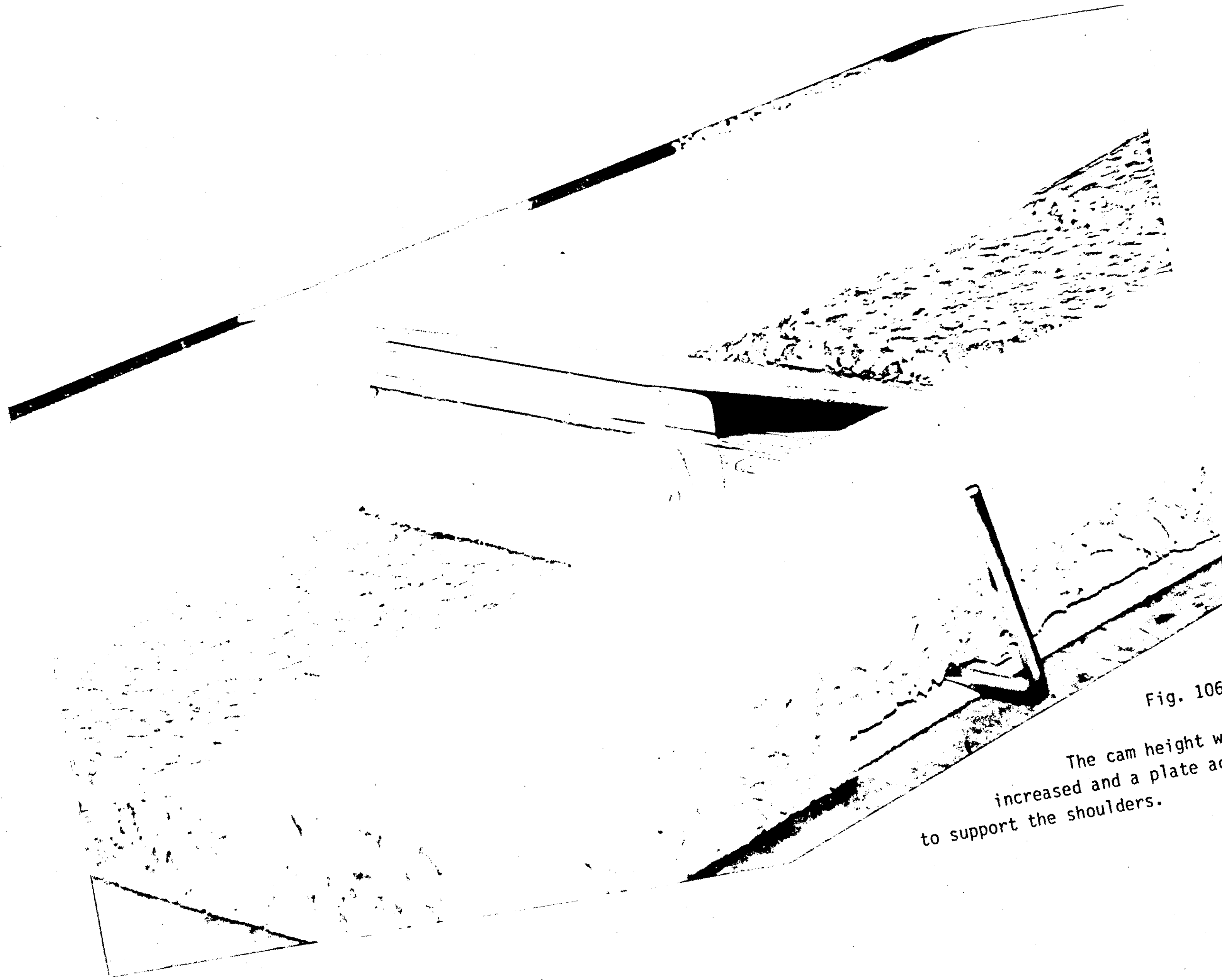


Fig. 106

The cam height was increased and a plate added to support the shoulders.

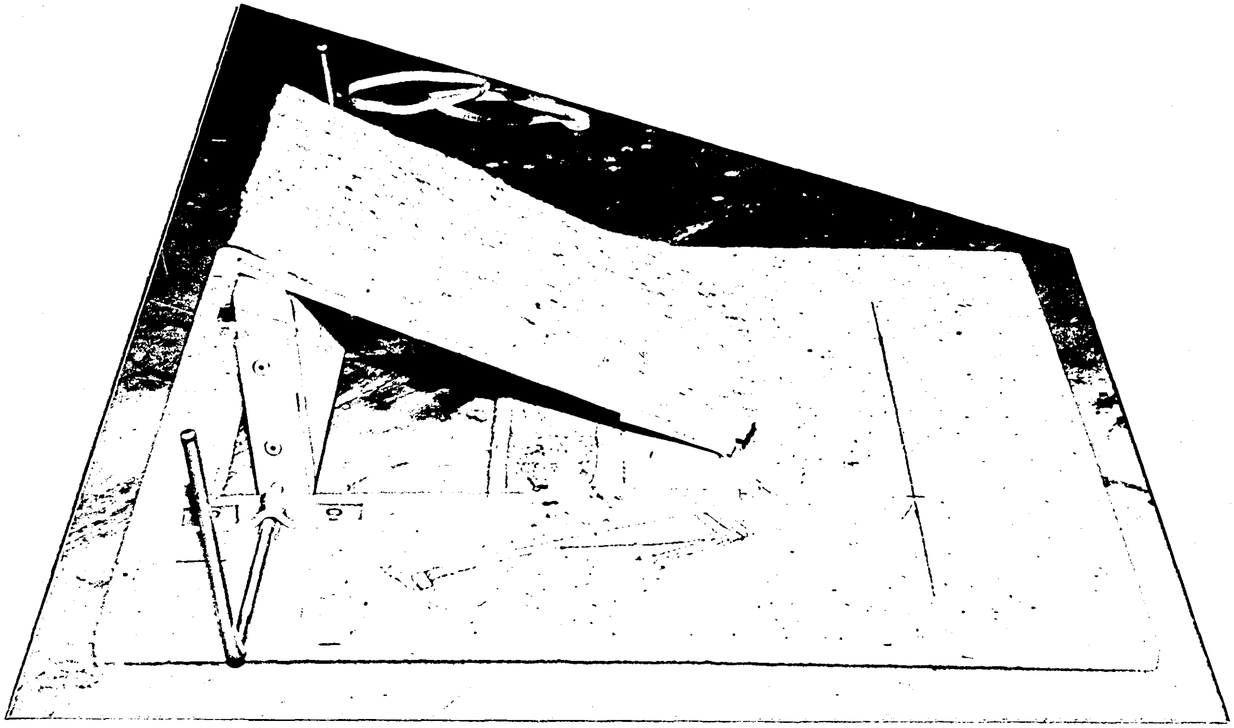


Fig. 107

A further development in the wooden cam device to enable the plate and its foam covering to fit within the 50mm thickness of the mattress centre.

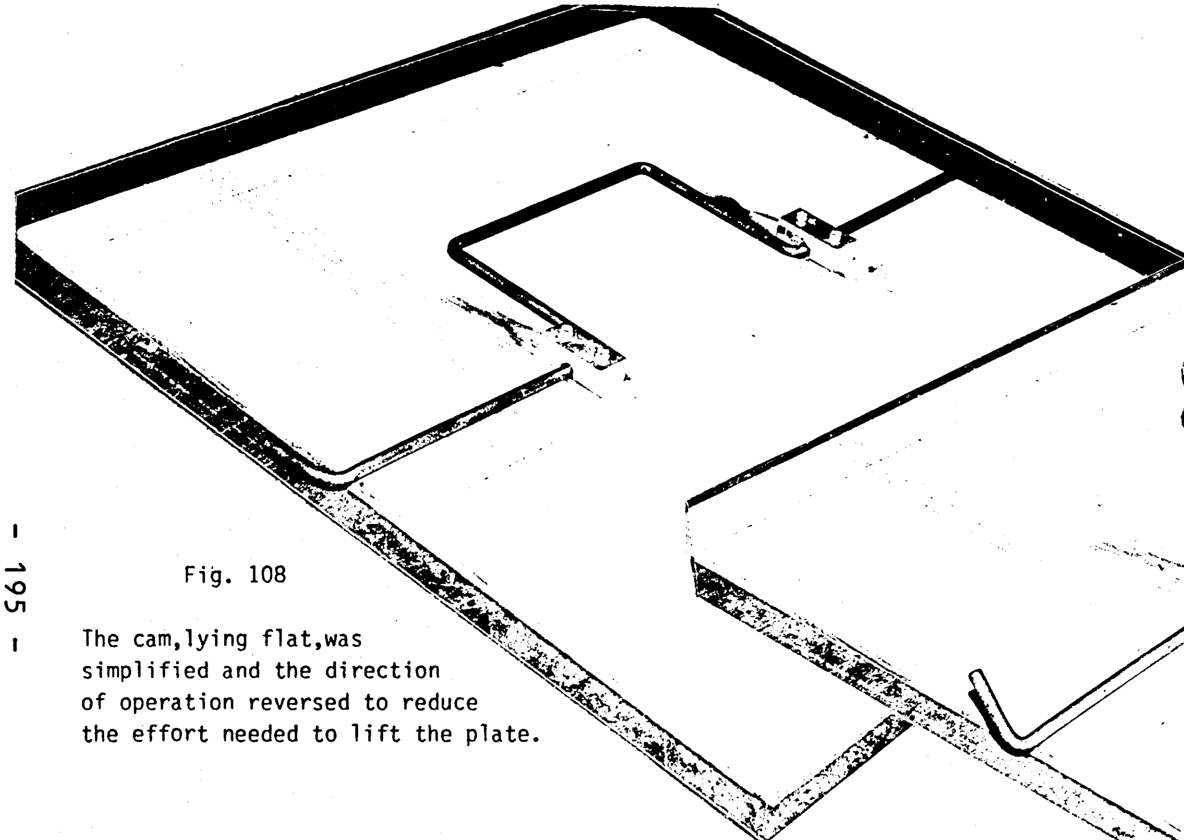


Fig. 108

The cam, lying flat, was
simplified and the direction
of operation reversed to reduce
the effort needed to lift the plate.

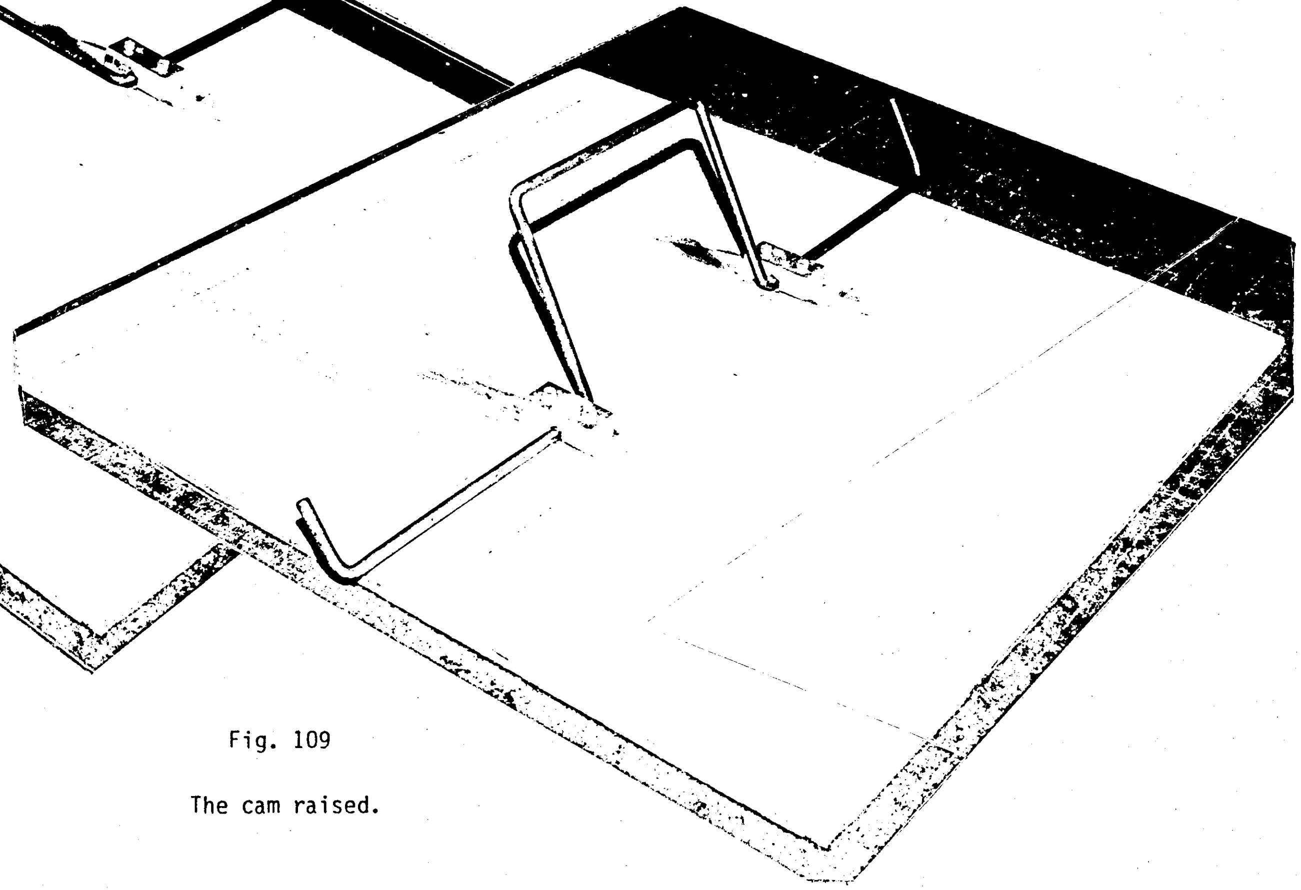


Fig. 109

The cam raised.

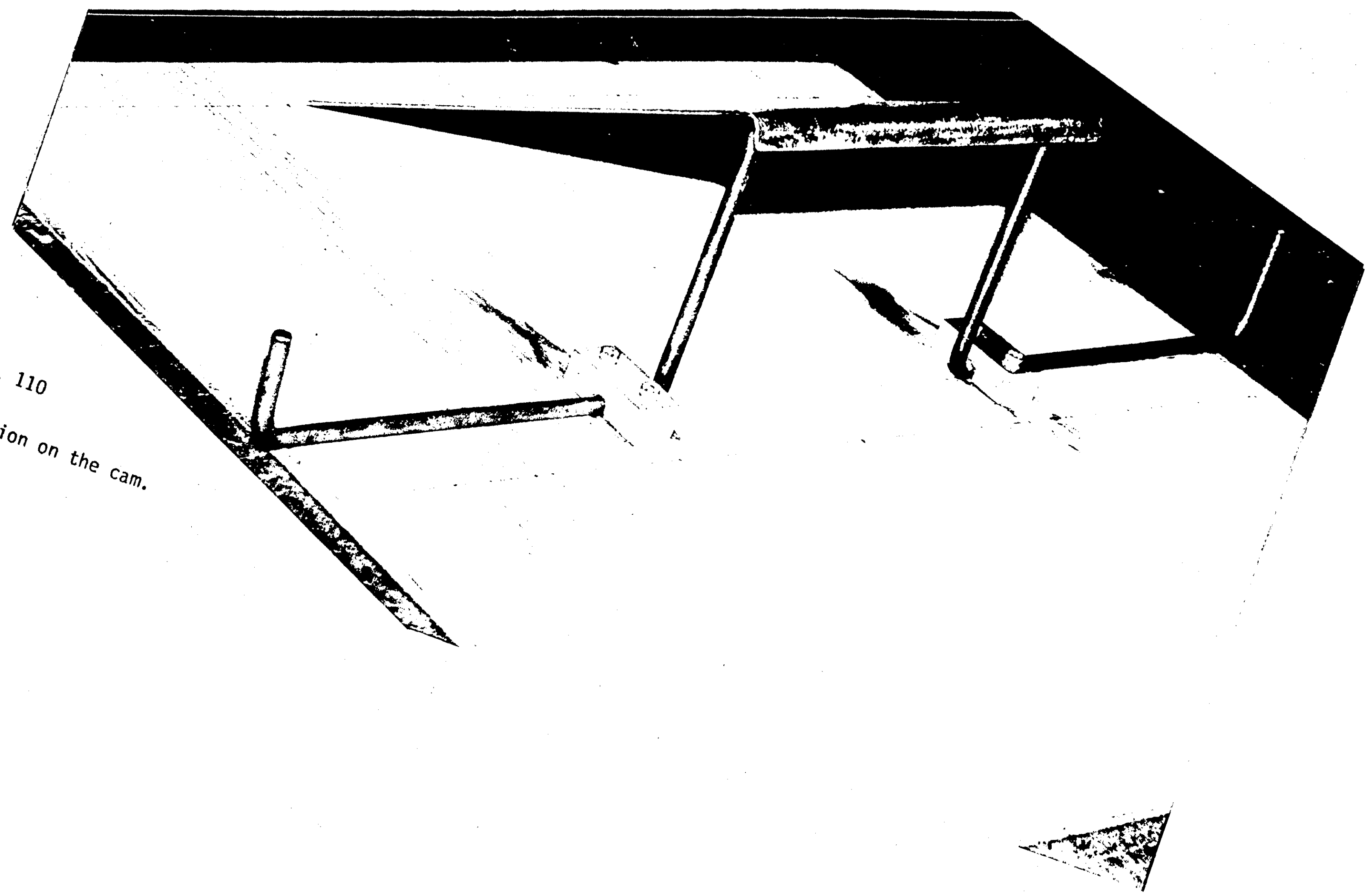


Fig. 110
The plate in position on the cam.

unattached to the trolley as this would tend to get lost or be stored away and not available when needed. Therefore, it appeared logical to examine ways of achieving the same results within a part of the trolley system and as the backrest had been already rejected this left the mattress. The constraints were the thickness of the foam in the centre of the contour mattress which is only 50mm whereas the sides are 100mm, the height required to raise the neck sufficiently to tilt the head back and keep an open airway which is 146mm from the base of the mattress and the necessity to keep the mattress comfotable for sitting patients at all times.

6.2.12 At first a cam shaped unit was developed to the shape of the neck with the head tilted back as shown in figs. 104 and 105. This was operated by two levers, one on either side which rotated the cam from the flat position inside the depth of the mattress foam to upright where it protruded above the foam to support the neck. This system proved to be very difficult to operate and it was decided that it would be more comfortable to add some support under the shoulders when raising the neck so a crank lever was designed that lifted a hinged plate as shown in fig. 106 and modified as show in fig. 107. This was made up and tried in a mattress but was found to be very difficult to operate because of the tension and friction in the material to be overcome as well as the weight of the shoulders and head to be lifted. It was decided then to try reversing the direction of operation of the crank on the plate as this would reduce the weight to be lifted at the start of the movement as shown in figs. 108, 109 and 110 and with adjustments to the material of the mattress this proved to be successful. Eventually a more elastic material was bought which solved the

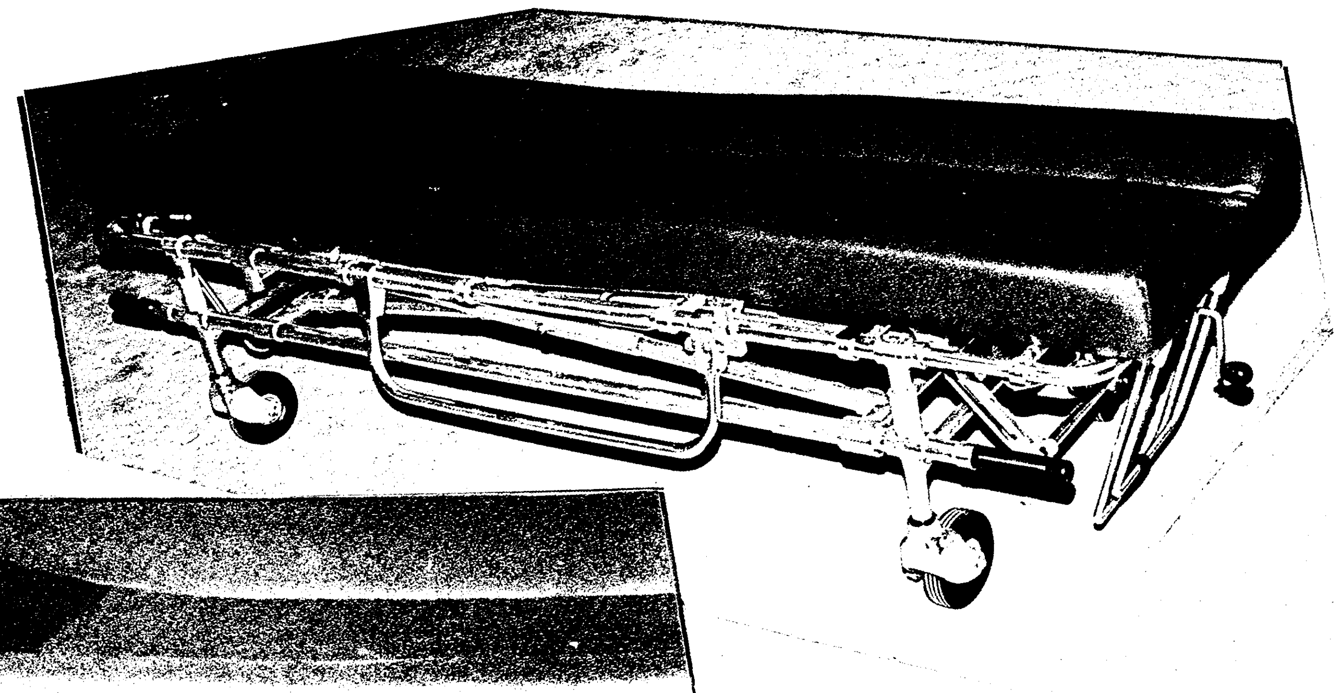


Fig. 111

The hyper-extension mechanism was built into a mattress. This is shown by the smooth black section.

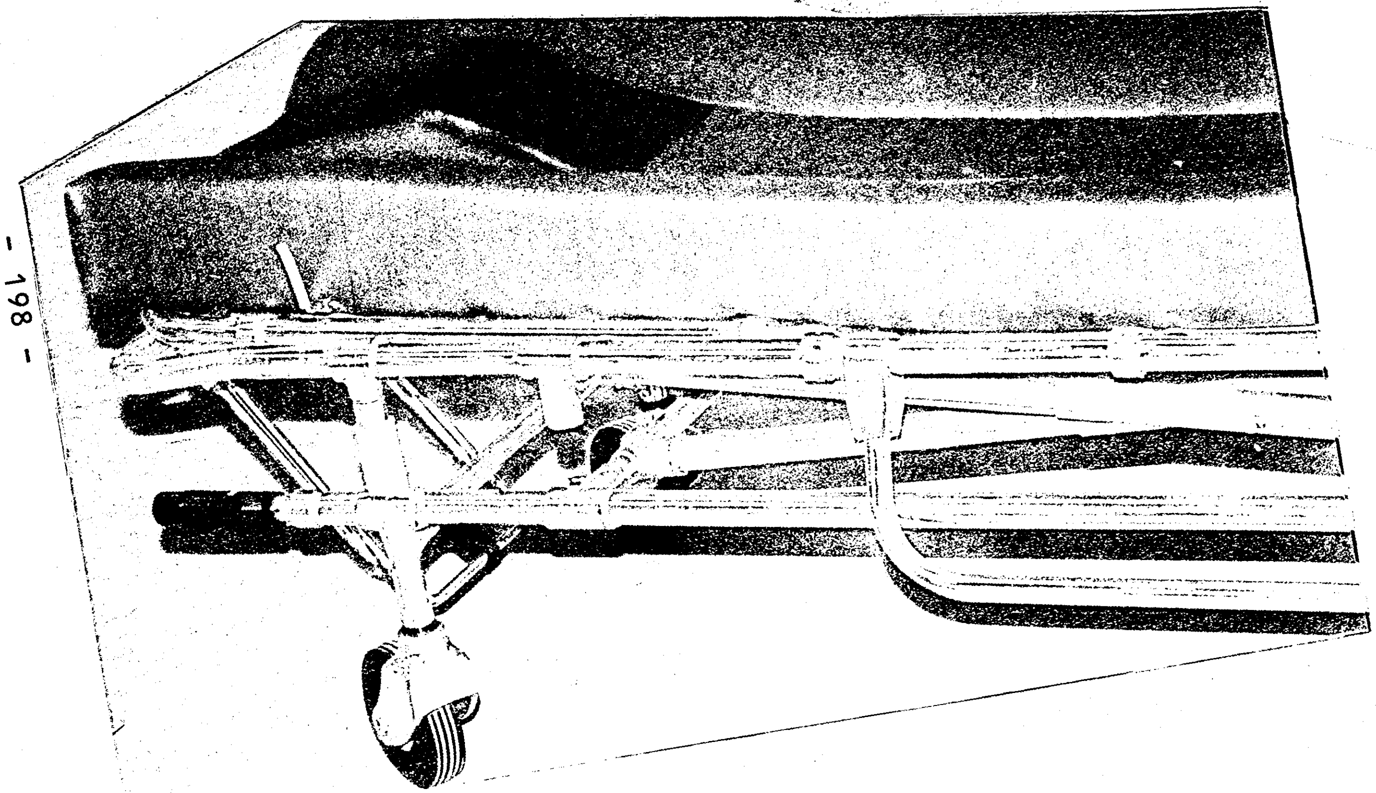


Fig. 112

The mattress with the hyper-extension position ready for use.

problem of stretch in the mattress cover when the mechanism is raised. This was prototyped in a mattress as shown in figs. 111 and 112.

6.2.13 As the position of the major functions working from the leg frame had now been resolved it was felt appropriate to examine the position of the side arms in relation to these as their location in the trolley frame is dependant on a clear space between the upper and lower frames in which they can be stored when not in use. The two longest sections of the side arms are the upright supports and to achieve the additional height over the existing trolley arms it is necessary that these fit horizontally under the trolley and extend towards the centre as far as the sub-frame. This is shown in fig. 102 which shows the position of the side arms when stored. The rails of the arm also fit horizontally but it was not felt necessary to have the ends of these as deep as the supports, therefore, they could be accommodated between the outer frame and the leg units. There are only two places in the structure of the trolley where the upright supports can be accommodated and these lie between the pivots in the central support unit of the elevating mechanism. The length of the side arm was determined by information gained from interviews with ambulance personnel and from personal observation which indicated that the arm should be both higher than the existing design and longer to give better security to the patient. These side arms, therefore, were designed to protect the patient from shoulder to mid-thigh when lying ina horizontal position.

6.214 Having determined the position of the side arms it was now possible to re-design the sliding and locking mechanism that enable them to slide out of storage and swing up into an upright position above the top frame. The basic slide component

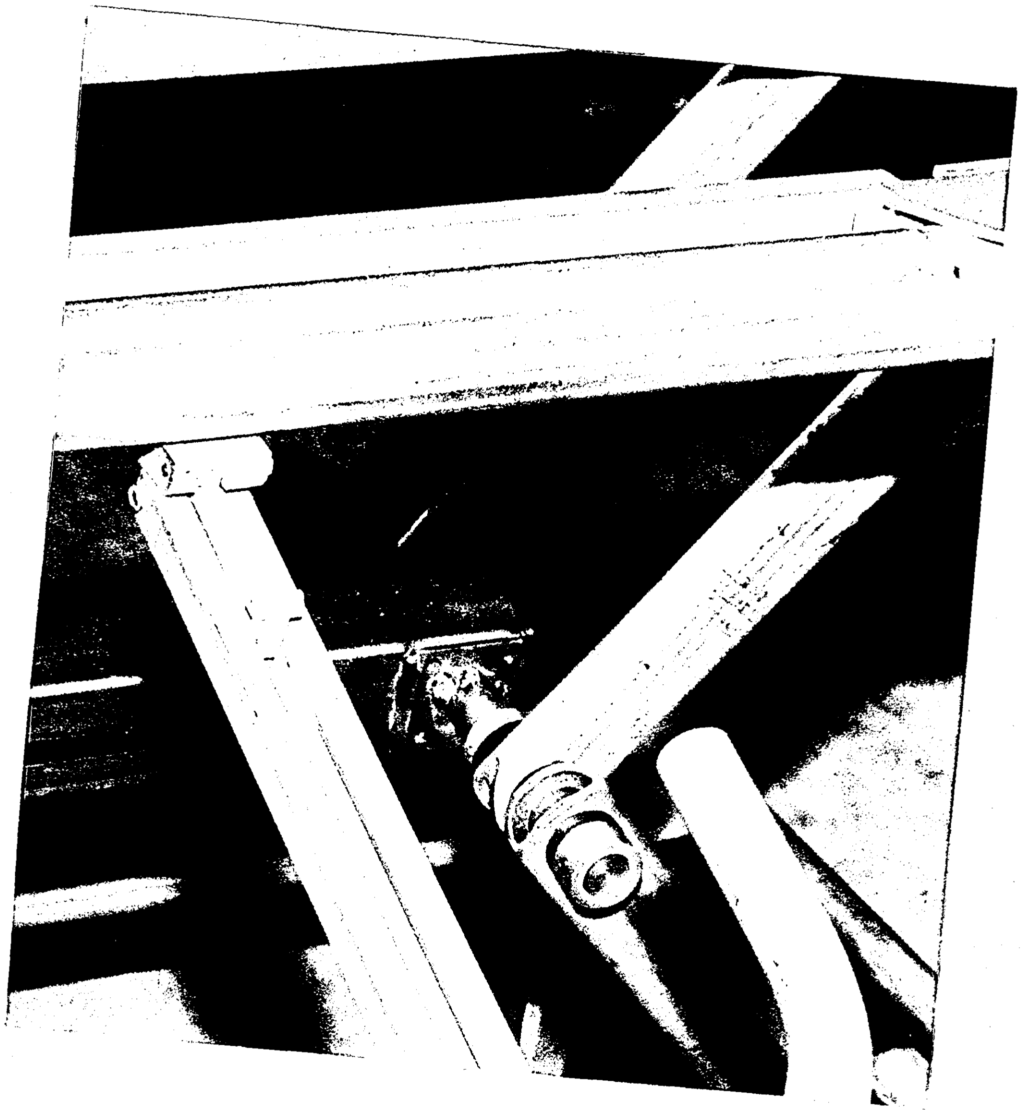


Fig. 113

The slide unit for the side arm on Prototype 2 during development.

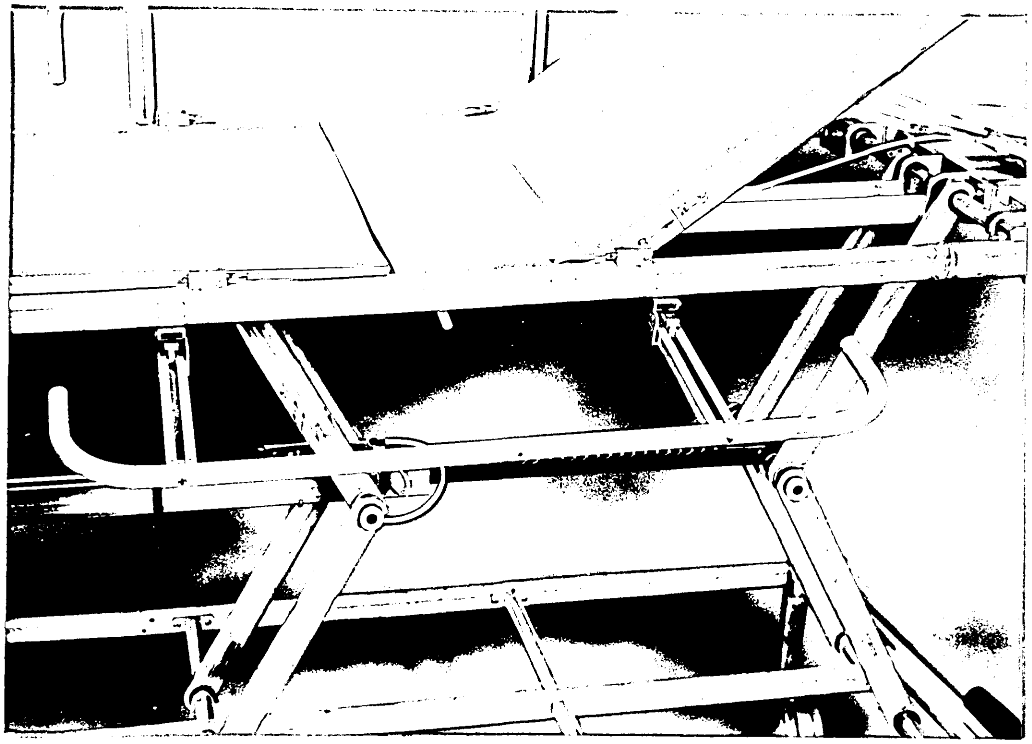


Fig. 114

The side arm in the horizontal position showing the slide in the final version used for Prototype 2. The lever that releases the arm when locked upright can be seen under the top frame between the two side arm uprights.

Fig. 115

The lock is a spring-loaded pin which locates in a hole in the bracket on the upright. It is released by a cable attachment to the lever under the top frame.

developed earlier during work on Prototype 1 was further detailed but the change in structure of the trolley ruled out the use of a full length slide unit as this would have required special fastening arrangements. This led to the development of the double slide unit as shown in fig. 113 where the slide component is held captive with limited movement and the upright forms a channel round it to slide the remaining distance. The slide component fits around the flat-oval tube of the top frame when the arms are upright but initial ideas to use this as part of the locking device were discarded because of their complexity. It was felt that both uprights would need locking but there should only be one releasing device and eventually the present system shown in fig. 114 was developed. Two identical spring-loaded pins in housing are fastened to the uprights of the side arms. When the arms are pulled out of storage and swing upright the lugs snap over the pins locking them into place as shown in fig. 115 then to release them a single toggle lever is situated between the two pins by cables, and when moved to one side the pins are retracted and the arm released. This completed the design of the major functions attached to the top frame of the trolley.

6.2.15 The remaining two features that required development from Prototype 1 were the carry handles and the towing handle. The carry handles were developed from the folding type idea as the problems of using a telescoping handle were considered too difficult. However, there were also problems with the folding handles as these were required to be not less than 51.6mm long but needed to be stored out of the way under the trolley and it had been decided when designing Prototype 1 that these handles would be located in the lower frame. It was also required that the handles should be easily

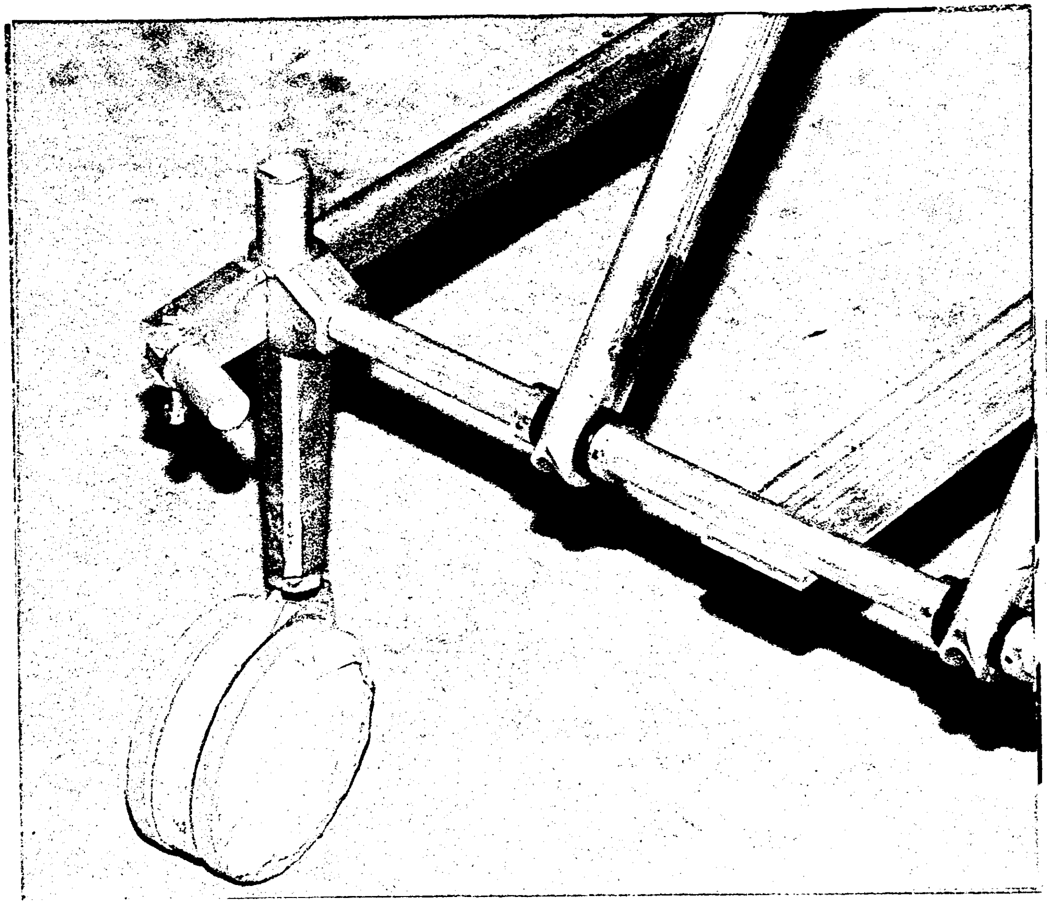


Fig. 116

The carry handle hinges attached to the lower frame of Prototype 2 during development.

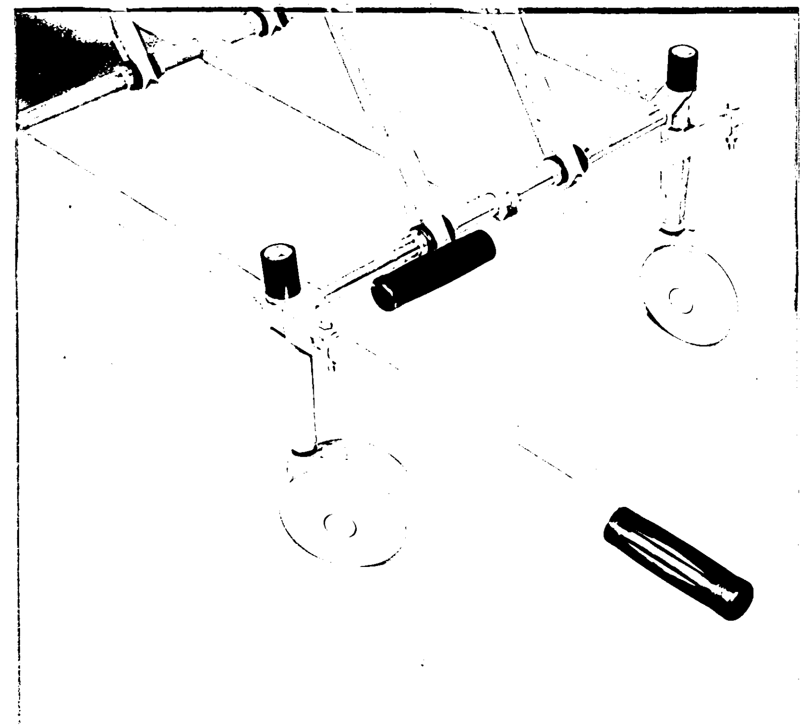


Fig. 117

The handles attached to the finished version of Prototype 2.

accessible and only one action to pull out or store them would be acceptable. Once again a full size drawing was used to enable various combinations of position to be assessed and it was finally decided to use two handles of equal length set at 62mm from the end of the lower frame. Fig. 116 shows the hinge casting in the lower frame. The distance they are set out from the frame allows one to fold inwards and the other to fold over it as shown in fig. 117. The handles at this distance out from the frame give the required minimum length for lifting but fit within the trolley width when folded.

6.2.16 The problems relating to the towing handles have not been resolved ina way that is acceptable as a reasonable and manufacturable solution, therefore, it was proposed that a handle designed for the existing trolleys be used but this has not been fitted to Prototype 2 as it leaves unsolved some of the major problems discovered during the user research. Suggestions to resolve this will be made in chapter 8.

6.2.17 The designs discussed above were all used to produce Prototype 2 in a workable form and they offer solutions to the problems outlined in chapter 3 as shown. They have also been designed within the context ofthe manufacturing facilities available for the production model. The next stage was the construction of Prototype 2 as outlined below.

6.3 Second Prototype - construction

6.3.1 Prototype 2 was designed to provide a working trolley capable of limited handling tests. As it was a single unit it was decided that cost of making the prototype together with the time required would not allow for all components to be made representative of a full production model, therefore, it would be appropriate to sacrifice some strength and visual qualities in order to obtain a working unit demonstrating the principles proposed for the operation of the functions of the trolley. Many features were developed as fabricated components representing the functions required but not representative of the strength nor visual qualities proposed, however, they allow the demonstration of the principles involved in operating each individual function.

6.3.2 As stated in para. 6.1.1. the components for this prototype were designed and made before assembly could take place as all components are interdependant and relate to one another either in function or in order of assembly. However, once the components were collected together assembly took place quickly. Some components were left until the basic assembly was completed as their shape, position and operation depended on the structure of the whole. The side arms were completed in design and prototype form after the initial main assembly, and the release mechanisms for the elevating mechanisms and backrest could not be fitted until other components were in place as the cables were required to pass around other features. It was also felt appropriate that the operating levers for these functions should be added last as some adjustment for position and grip hold could then be accommodated without major change.

6.3.3 On assembling the elevating mechanism to the top and lower frames again it was found that the spring in the system was unacceptable. This was modified by increasing the size of the cross pivot bars on the lower frame to 22.225mm from 19.05mm diameter and by the addition of a central longitudinal bar tying the cross pivot members on the lower frame together to prevent their movement both horizontally

Fig. 118

The finished version of Prototype 2 in the lowered position.

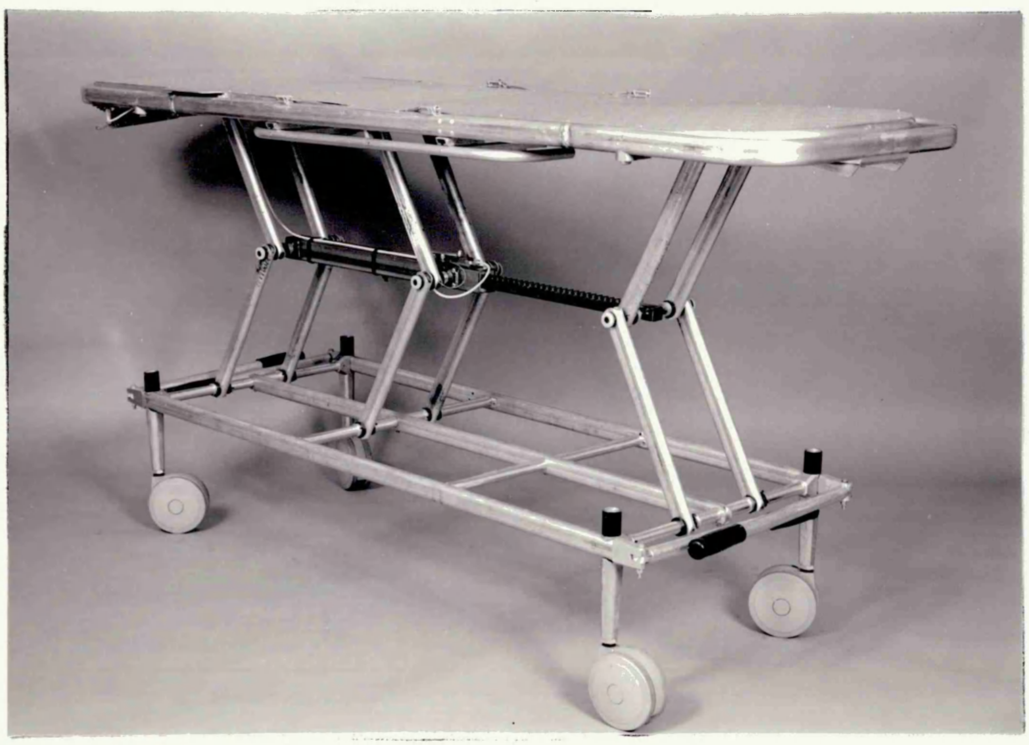


Fig. 119

The elevated position.

Fig. 120

Prototype 2 elevated and in the Fowler's position with one side arm up.

and vertically. This succeeded in considerably increasing the rigidity of the trolley structure when elevated.

6.3.4 Finally on completion of all adjustments and modifications the top frame was sheeted with patterned aluminium sheet fastened in sections to the moving components on the top frame as shown in figs. 118, 119 and 120. The trolley was now ready for evaluation of the handling qualities but the use of stock materials for the reason given above has, however, led to an increase in weight of 3KG over that of the existing trolley and 8Kg more than that recommended. This will be resolved in the production model with the use of the correctly designed flat oval sections. It will affect the handling tests and will need to be taken into consideration during the evaluation.

7 SECOND PROTOTYPE - Handling Evaluation

7.1 Introduction

7.1.1 Prototype 2 is intended to demonstrate the working principles of the new design and to enable an ergonomic assessment to be made of its handling properties. The construction of Prototype 2 enables simple structural tests to determine stability to be carried out. The features of the trolley can be handled and examined in a 'use' situation, similar to that demonstrated at the start of the project. For evaluation purposes handling can be compared to the existing trolley design with the exception of the extra weight due to the material used as explained earlier.

7.1.2 The evaluation procedures were devised to enable the new design to be handled in a similar situation to that in which the original trolley was demonstrated. A comparison of the results would then enable the new design to be evaluated against the performance specification. It was felt important to record the reactions of the ambulance men and their criticisms or suggestions for refeence during further developments of the design.

7.2 Handling evaluation

7.2.1 It was decided that the handling evaluation should be carried out by officers of the same ambulance station at which the original handling demonstration was given. This would enable those officers who had contributed to the information gathering process, an opportunity to handle the new trolley and compare it with the existing one, and a set of results to be obtained comparable with the original exercises. To achieve this a session was arranged at the ambulance station to demonstrate the new trolley and carry out certain handling exercises both in and out of the ambulance.

7.2.2 The handling exercise began with a demonstration by the author of the features of the trolley and their operation. This was followed by a short period in which the trolley was handled inside an ambulance by both the author and ambulance officers and ended with a handling exercise without the ambulance as unfortunately this had to go out on duty. This exercise enabled two officers to handle the trolley and all its features from floor level as in a hospital room. In the latter stage of the exercise the author again acted as casualty allowing the ambulance officers the opportunity to use the trolley in a semi-realistic manner i.e. carrying a person though not one requiring the care of a sick or injured person.

7.2.3 The initial handling demonstration consisted of the operation of all the features on the trolley in order to show both the facilities provided and their method of operation. This provided the first opportunity for the ambulance officers on duty at the station that day to examine the trolley. Initial comments and discussions arising from this are given below.

1) <u>The width of the new trolley</u>

It was felt by some officers that the extra width, relative to the existing trolley design, could cause problems in the ambulance by reducing the width of the aisle between trolleys (there are usually two, one on either side of the ambulance) thus restricting their ability to carry wheel chairs in the ambulance. Some officers also felt that the extra width could cause a problem for some small elderly persons who already have difficulty in sitting back on the existing trolley when travelling seated sideways. Conversly, other officers felt the extra width to be an advantage allowing easier accommodation for the larger patient who is at present made uncomfortable by the restriction of the width between the side arms in the existing design.

2) Elevating mechanism

This was generally considered to be an improvement on the existing system and to look stronger and more stable. There were no further comments about this mechanism but it was felt by one ambulance officer that the cable release presented a complicated appearance and could be difficult to adjust. This view, however, was not shared by the other officers who considered the release system less complex than the one in use now.

3) The Fowler's position

This feature provoked many adverse comments, Particularly about the operating handles. It was felt that these projected too far beyond the trolley frame and would possibly cause injury to the legs of persons sitting sideways on the trolley especially if their legs were already injured or they suffered badly from varicose veins. It was also felt that the single operation did not allow for adjustment of height or leg length should the maximum height provided be found uncomfortable.

4) Side arms

It was generally felt that these provided a big improvement on the existing system with their extra height and length. The method of operation, sliding out and swinging up, was not considered to be a problem should the present limitations of slackness in the slides and the general weakness of the fabricated parts on the prototype be overcome by the design of a casting for this feature.

5) Weight

This was discussed as the prototype is heavier than its estimated weight of 30kg and gave a false impression when handled. It was explained that the actual weight of a production model would be equivalent to the weight of the existing trolley.

6) Wheels

The British Castors 'Travelaid 125' castors used on the prototype were very favourably received. Unfortunately, a brake version of this castor is not yet available. However, it was appreciated that the smooth exterior surfaces would not catch on any projections and the double tyre system gives greater stability.

7) Carrying handles

These, unfortunately, could not be used during the handling tests as the prototype version are not strong enough. However, the folding system of operation and storage appeared acceptable providing the castings attaching the handles to the lower frame are rounded off to prevent damage. For ease of machining those on the prototype had been left square but these would be castings on a production model. An interesting suggestion, however, was that perhaps the carrying handles would not be necessary as the top frame provided adequate handling areas for lifting.

8) Trolley top

It was observed by one officer that the sheeting would be noisy with movement of the trolley and vibration during the vehicle ride. However, it was explained that the present method of sheeting was used on the prototype for appearance only and this would be accommodated in the production version. It was also commented that the sheeting would prevent damage to the under surface of the mattress as happens at present.

9) <u>The Hyper-extension mattress</u>

This was very well received and all ambulance officers considered it an improvement on existing equipment, which in most cases would consist of a rolled blanket.

7.2.4 It was noticeable that there were no comments about the backrest or Trendelenberg position. It was not possible to follow this up due to the short time the ambulance crews were available. However, these appeared to be accepted as reasonable solutions to the problems identified concerning these positions.

7.2.5 The next phase of the exercise involved handling the trolley in the ambulance. The trolley was placed in the locks in both the sitting (inner) position and the nursing (outer) position. This is shown in figs. 121 & 122. All the facilities except the elevating mechanism were operated in the nursing position to assess access to the operating handles and their ease of use. It was noted that the trolley fitted easily into position in the locks because of the extra 12.5mm clearance under the lower frame giving a total of 266.5mm between floor and lower frame. Once in position in the ambulance it became apparent that the fears expressed concerning the width were unfounded and that there would be adequate room for wheelchair access.

7.2.6 The operation of the facilities demonstrated that all operating handles are accessible and that these can be used with the trolley in the nursing position. Fig. 123 shows the trolley with the

Fig. 121

Fig. 122

Prototype 2 in the ambulance in both the sitting and nursing position.

Testing the features of Prototype 2 in the ambulance to assess handling ability.

Fig. 123

Prototype 2 being elevated.

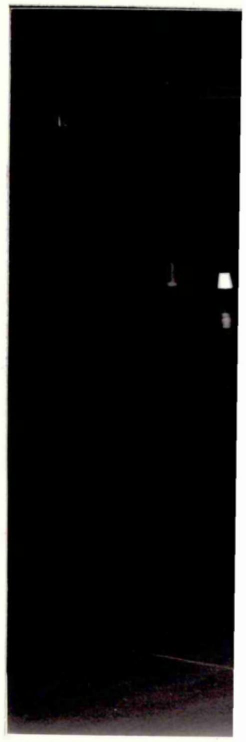


Fig. 126

The backrest being raised from horizontal to its maximum lift.

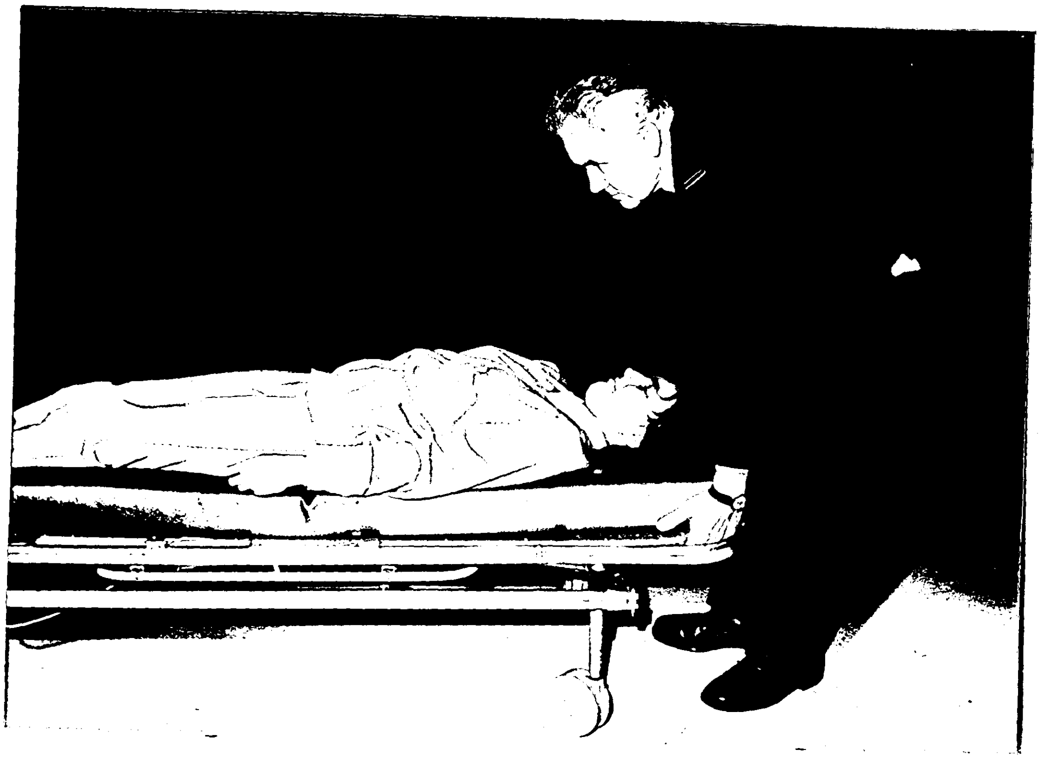
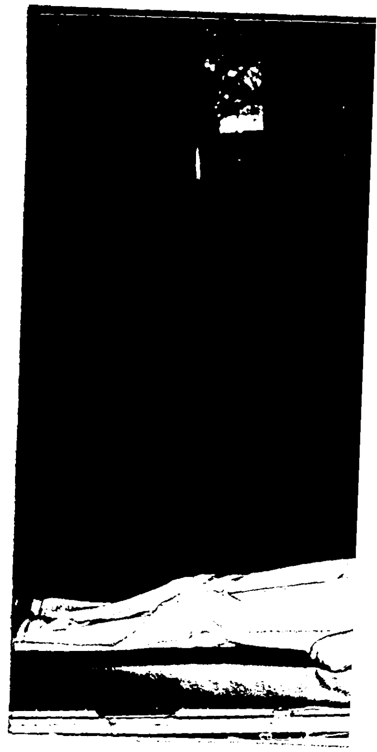


Fig. 129

Fig. 130



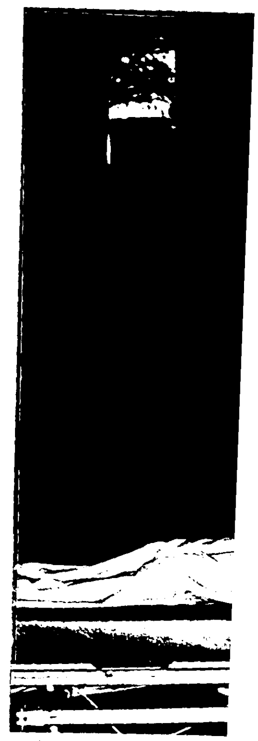


Fig. 133

The operation of the Fowler's position.

The side arms slide out then are swung upwards to lock against the side of the trolley

Fig. 134

backrest up and fig. 124 shows it in the Fowler position with the author acting as casualty. This position felt very comfortable as secure. Fig. 125 shows the trolley in the Trendelenberg position. The release handle for this was found to be easily accessible from the side at the foot of the trolley.

7.2.7 The third section of the exercise, as mentioned above, involved two ambulance officers who handled the trolley using the various features with the author acting as casualty. For the purpose of most of the exercises a contoured, non-standard wide mattress was used in preference to the narrower standard mattress prototype incorporating the hyper-extension features. The trolley was elevated as shown in figs. 126, 127 and 128. The ambulance officers commented that the elevating mechanism was easier to use than the existing ratchet unit and that the position of the operating handle at the foot was comfortable and easy to use. As casualty the author found that there was no feeling of instability and the wider mattress was far more comfortable than the standard version.

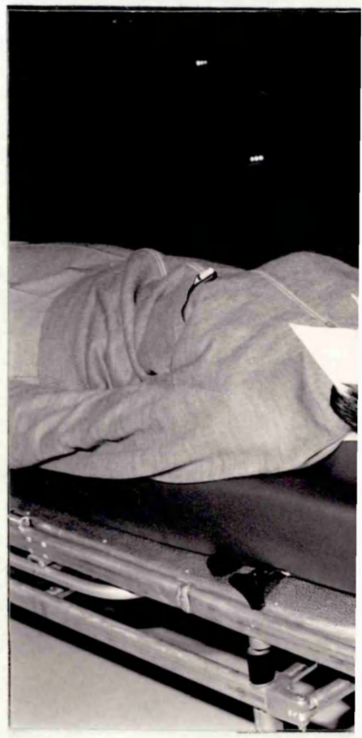
7.2.8 The backrest was operated as shown in figs. 129 to 132 and, as stated earlier , appeared to be accepted. There were no difficulties in operating the release mechanism but it was not obvious to the ambulancemen that the ratchet system allowed the backrest to be raised by lifting it and only required the release mechanism when lowering. They used the release handle when operating it in both directions.

7.2.9 Fig. 133 demonstrates operating the Fowler's position about which the majority of comments were made in the initial stage of the exercise. The side arms were also demonstrated as shown in figs. 134 to 136. As mentioned earlier these were considered a major improvement in patient security

The hyper-extension feature in the mattress and demonstrating its use.

Fig. 137

Fig. 138



and usability.

7.2.10 The hyper-extension mattress was next demonstated as shown in figs. 137 to 140. As stated earlier, this was considered a very useful feature though it was remarked that the head position was not tilted back far enough to enable intubation, however, it is sufficient to maintain an open airway. As casualty the author found this position reasonable though not comfortable. There was no discomfort from either the edge of the mechanism frame or from the neck supporting edge of the lifting section.

7.2.11 The final handling exercise comprised simple stability tests using a 'York 4' trolley and the new trolley prototype. These consisted of taking a basic measurement of the height of the trolley frame when elevated then measuring the height to same position on the frame with:-

a) A load on the corner of the trolley
b) A load on the centre of one side of the trolley

It was felt realistic to use a person as the load so in this instance, therefore, the load comprised the author's full weight but in both cases the deflection of the corner position caused a feeling of insecurity and the load was reduced slightly by resting one foot lightly on the ground. The full weight was used for the side loading measurements. There was no feeling of instability when sitting on the side of the prototype trolley nor any tendancy for this trolley to turn over. Figs. 141 to 143 illustrate this exercise and the results are given below:-

a) <u>Corner deflection</u>

	York 4	Prototype
Starting height	765mm	793mm
with load	743mm	765mm
deflection	22mm	28mm

The loading tests were carried out on a 'York 4' trolley and Prototype 2

Fig. 141

b) Side deflection

	York 4	Prototype
Starting height	765mm	793mm
with load	745mm	785mm
deflection	22mm	8mm

The starting heights were arbitrary but remained the same for each trolley throughout the tests.

7.3 CONCLUSION

7.3.1 The prototype was well received at the ambulance station by those officers present, and there were no adverse comments about the basic principles. Most comments concerned those details such as the handles for the Fowler's position, that have not been fully resolved owing to the difficulty of fabricating complex shapes. There were some problems in actually operating the prototype due to the nature of its construction. The frame is slightly twisted due to the welded joints in the top frame and to the method of obtaining the flat-oval sections. During testing the sheeted top surface bowed causing the Fowler's position mechanism to become mis-aligned and stiff to operate but despite these problems all features were operable both in and out of the ambulance.

7.3.2 The stability tests proved the new trolley as stable as the existing one and more stable with a side load. It was also felt that the new elevating mechanism offered greater stability and easier to operate because the ratchet released without catching. Similarly, the side arms were generally considered an improvement because of their extra height and length. The Fowler's position was the only feature to attract criticism and it was felt that enough information had been obtained from this visit to enable design improvements to be formulated for the production version and the wish was expressed by the ambulance personnel to see an advanced prototype or production version in service for user trials.

8 Production Model Recommendations

8.1 Introduction

8.1.1 The handling evaluation described in the previous chapter exposed several detail areas that require re-designing to remove possible difficulties. Similarly there are many areas where the method of construction of the prototype varies considerably from the proposed method of production. Using production methods it will be possible to improve both the final form and operation of these components. These improvements and the proposed production methods are outlined below.

8.1.2 The production facilities available at present consist basically of tube bending, sand casting, drilling with the use of jigs and some lathe work. However, it would be possible to sub-contract machining work where necessary. It may also be possible depending on quantity to use more accurate casting methods such as die casting. These facilities are based on the use of a metallic material of which some portion will be in hollow section. Of the materials available an aluminium alloy was chosen for the main structure for the following reasons:-

1) Its light weight relative to steel.
2) Its ability to support a polished finish without additional protective treatment.
3) The manufacturer's familiarity with this material.
4) The ability to obtain extruded section to a specific shape.
5) Cost - though expensive aluminium is probably cheaper than the other light weight materials available.

8.1.3 Although aluminium has been chosen as the basic material there remains the possibility of using polycarbonate mouldings for some components and for

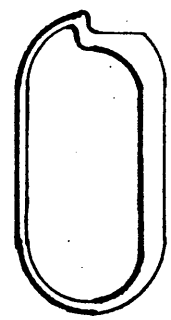


Fig 144

The flat oval has a
thickened side to enable
castings to be attached
and a notch to allow
the sheeting to remain
flush with the top of
the oval tube.

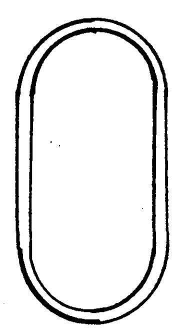


Fig 145

the trolley bed. However, in this instance aluminium would still be required for the trolley frame and the majority of the components. The alloy specificed is B.A. 6063TF. with a tensile strength of 185 N/mm^2 and these are the figures on which the calculations given in Chapter 4 are based. The following paragraphs discuss the proposed methods of production and the final design of individual components using this material.

8.2 Component designs and Production Methods

8.2.1 The Frame

As described earlier the basic frame is constructed from a flat oval hollow section. It is proposed that this should be extruded to the specified shape shown in cross section in fig. 144. This section has a flat surface on the upper inside edge as shown, to receive the sheeting forming the bed surface. The outer edge of this flat surface provides both a locating feature and an integral finishing strip preventing the sheet from overlapping the edge of the section. This section also has a thickened internal wall on the same side as the flat edge to provide an adequate wall thickness to which the other components can be attached.

8.2.2 The Elevating Legs

The section used for the elevating legs could, if necessary be the same as that used for the frame, but as neither the flat surface nor the thickened wall is needed it would be carrying unnecessary weight. It would also require special care to ensure that the legs were assembled with the flat edges in a sequence that made them visually pleasing and not assembled randomly. It would be more suitable to use a section with even wall thickness as shown in fig. 145. However, this would require the use of a second die for extrusion.

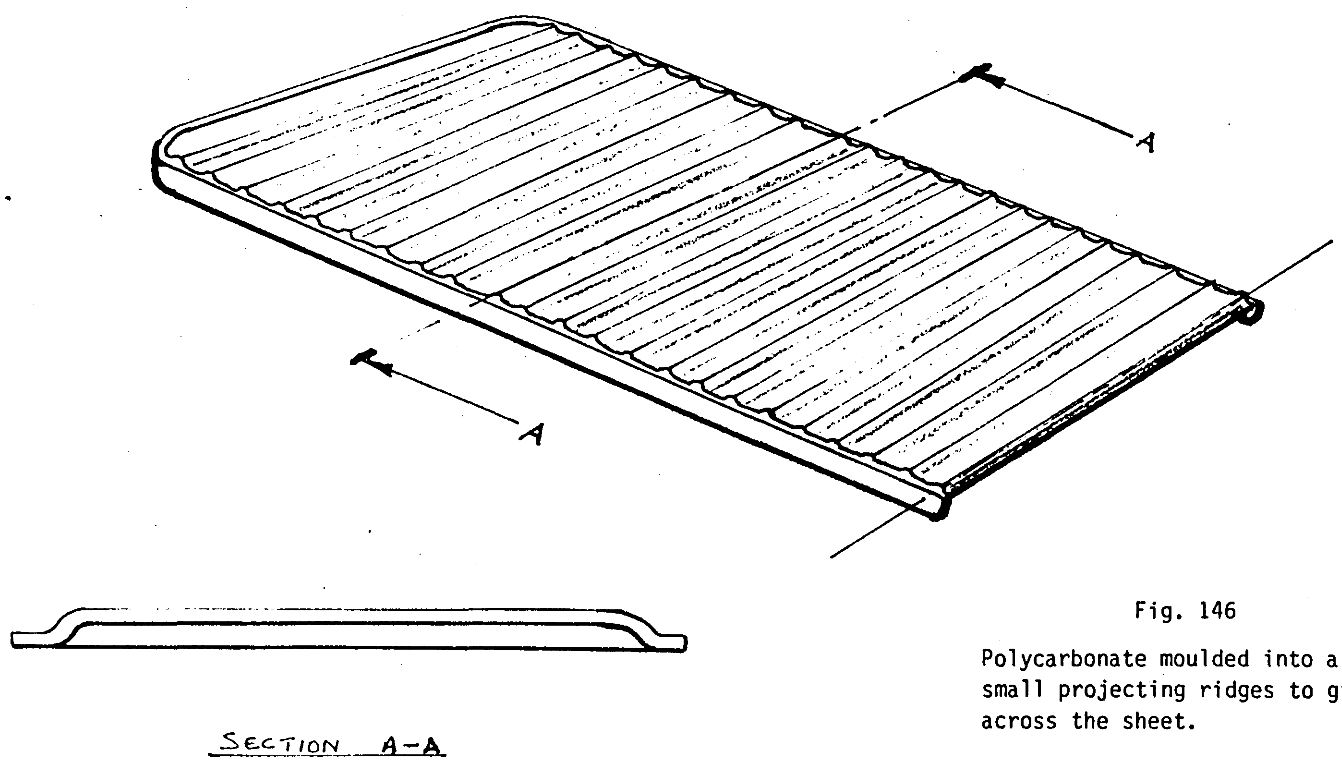


Fig. 146

Polycarbonate moulded into a series of small projecting ridges to give stiffness across the sheet.

8.2.3 The Trolley Bed

This is formed from diamond patterned aluminium sheet. For the prototype the sections were cut to size and fastened to the top frame with self tapping screws. It was found in the handling evaluation that the sheeting required more support at the joins between sections to prevent sagging. It is proposed to vacuum form these sections in which case they may be strengthened by careful design of corrugated or ribbed patterns that can be integrally moulded as shown in fig. 146.

8.2.4 Fowler's Position

There were two relevant complaints made about this feature during the handling exercise. The first concerns the handles used to operate this position which project beyond the outer edge of the top frame and it was felt this would possibly cause injury to certain patients. It would be possible to avoid this problem by either raising the handle enough to leave finger room between it and the top frame or by making the handle in such a way that all edges are smooth and rounded to prevent injury. Fig.147 shows the first suggestion. The advantage of this lies in the ability to keep the handle within the outer edges of the top frame but the dis-advantage lies in the psychological effect of lowering an object onto another with fingers between the two, giving rise to the fear of trapping them. The second suggestion is shown in Fig. 148 has the advantage that there is no risk of trapping fingers but the disadvantage that it still projects beyond the outer edge of the frame. It would, however, require the building of these as prototypes, then handling tests to determine which suggestion is the most satisfactory.

8.2.5 The Fowler's position for the prototype has been manufactured by fabricating the individual components from extruded sections and sheet then

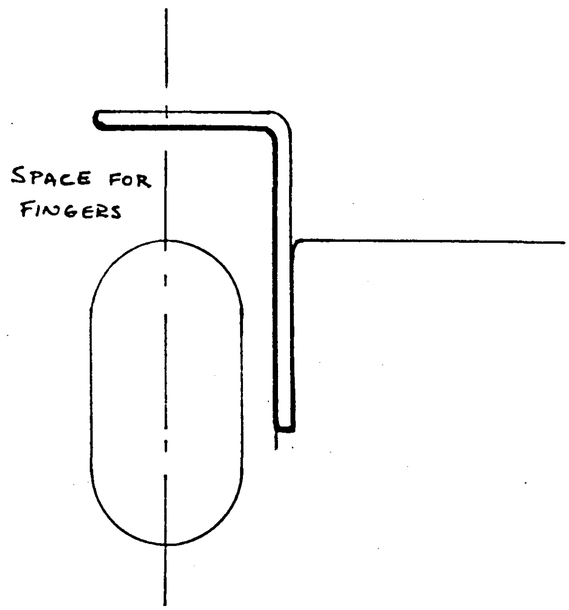


Fig 147

Fowler's Position operating

handle alternatives

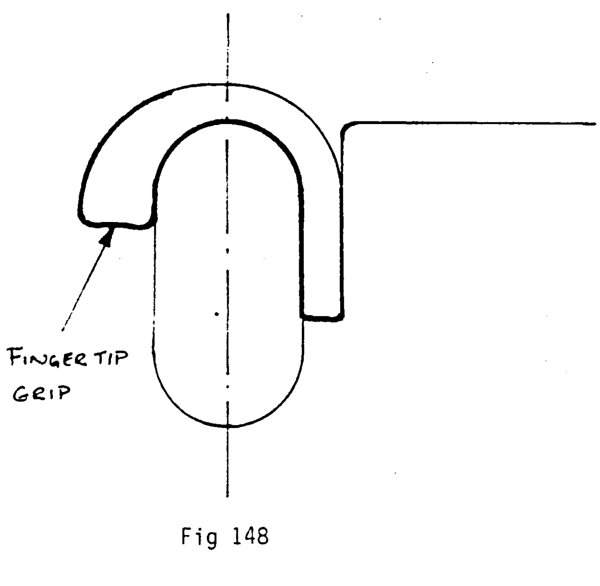


Fig 148

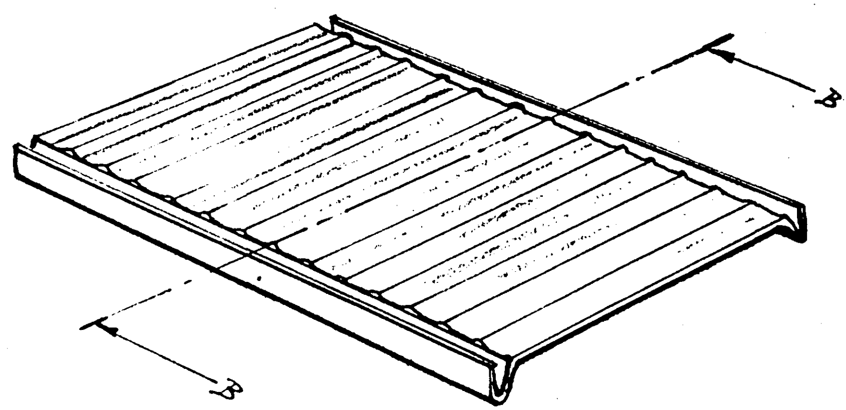
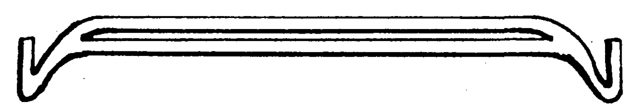


Fig. 149

Fowler's position section using polycarbonate moulding,



SECTION B-B

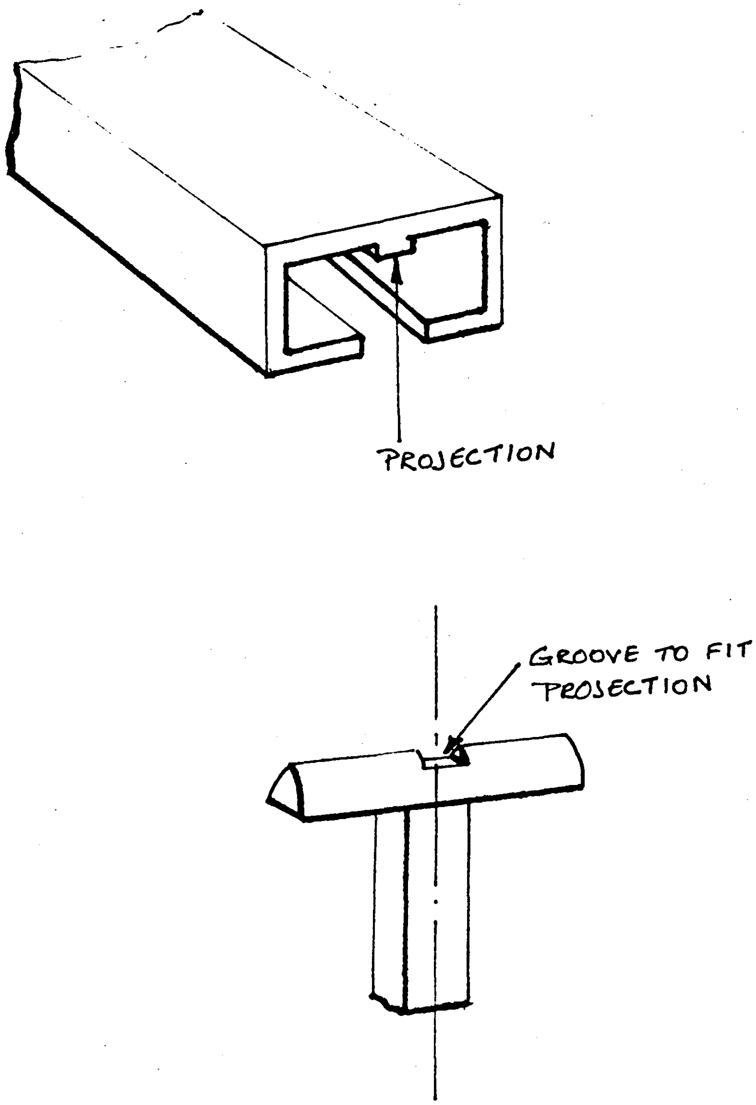


Fig. 150

Side arm slides grooved to reduce looseness.

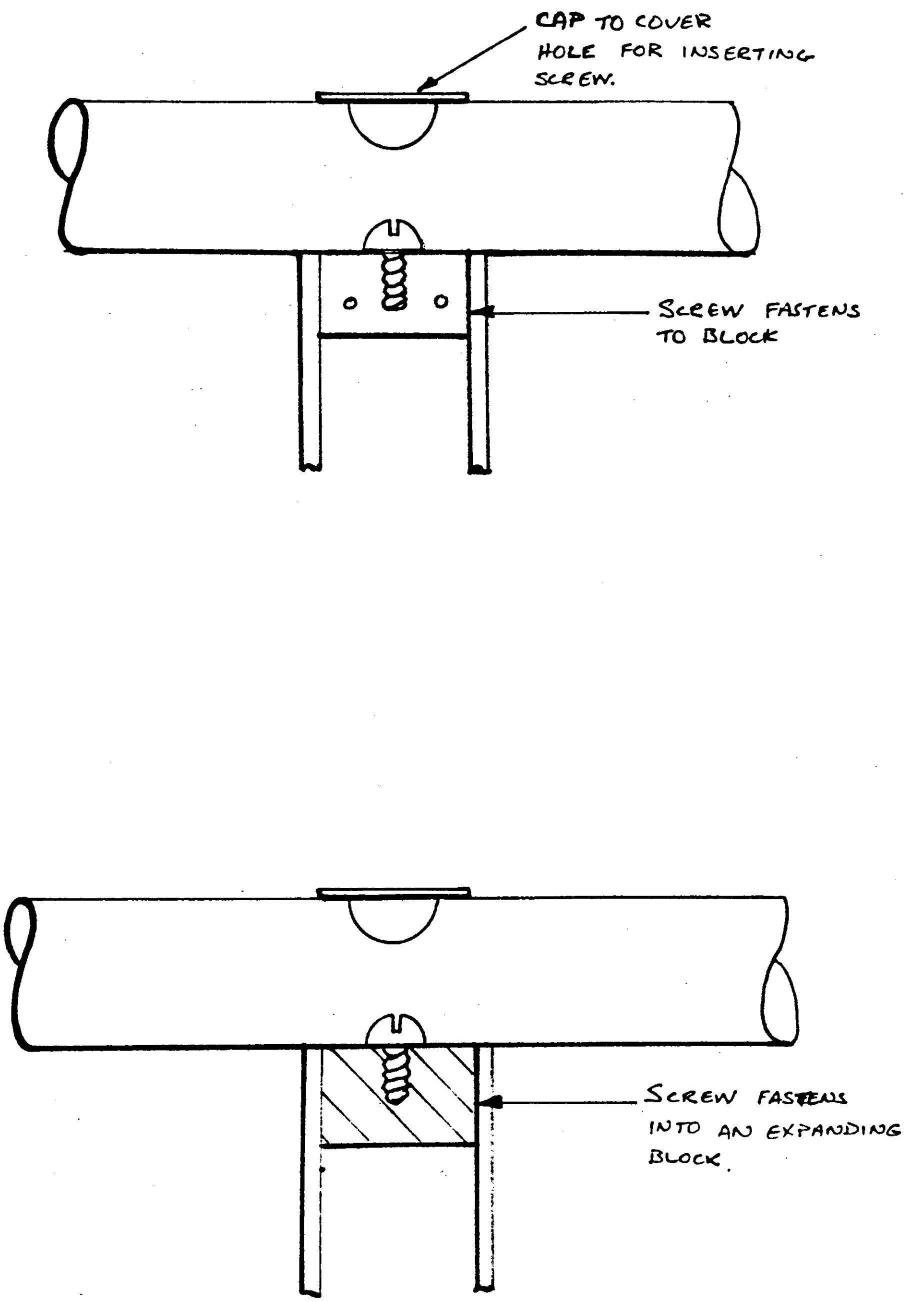


Fig. 151

Side arm fastening to support.

assembling them. For this the only operations required are drilling, cutting and shaping the parts, however, the handles cannot be fabricated and would be suitable for casting. It is proposed, however, that the sections should be made as whole units using vacuum forming. This would allow the top sheet and side sections to be moulded together as one unit as shown in fig. 149, and the handles attached to these. These could then be combined with the same method of producing the trolley bed as discussed above in 8.2.3.

8.2.6 Side Arms

It is noticeable on the prototype that the two struts on the side arms do not move parallel to each other when the arms are pulled out. This is due to lateral movement in the sliders which is necessary to allow clearance when hinging the arms upwards. There is also a problem with looseness of the slide unit bracket where attached to the frame due to the fabrication of the unit. It is proposed that the sliders and slide unit should be castings and should carry a groove in the centre of the sliders as shown in fig. 150 with the matching projection inside the slide unit also shown in fig. 150. This would then prevent any internal movement and cause the arm struts to travel parallel when pulled out. The arms themselves are formed from tube bent at the correct length to give the end sections which are finished with end caps. The struts are made of extruded section and the arms could be attached to these in either of the two ways shown in fig. 151. This would be a fabrication and assembly process.

8.2.7 Carry Handles

On the prototype the hinge system for the carry handle is inadequate to support the weight of the trolley without a casualty. This needs redesigning to strengthen the hinges yet retain the

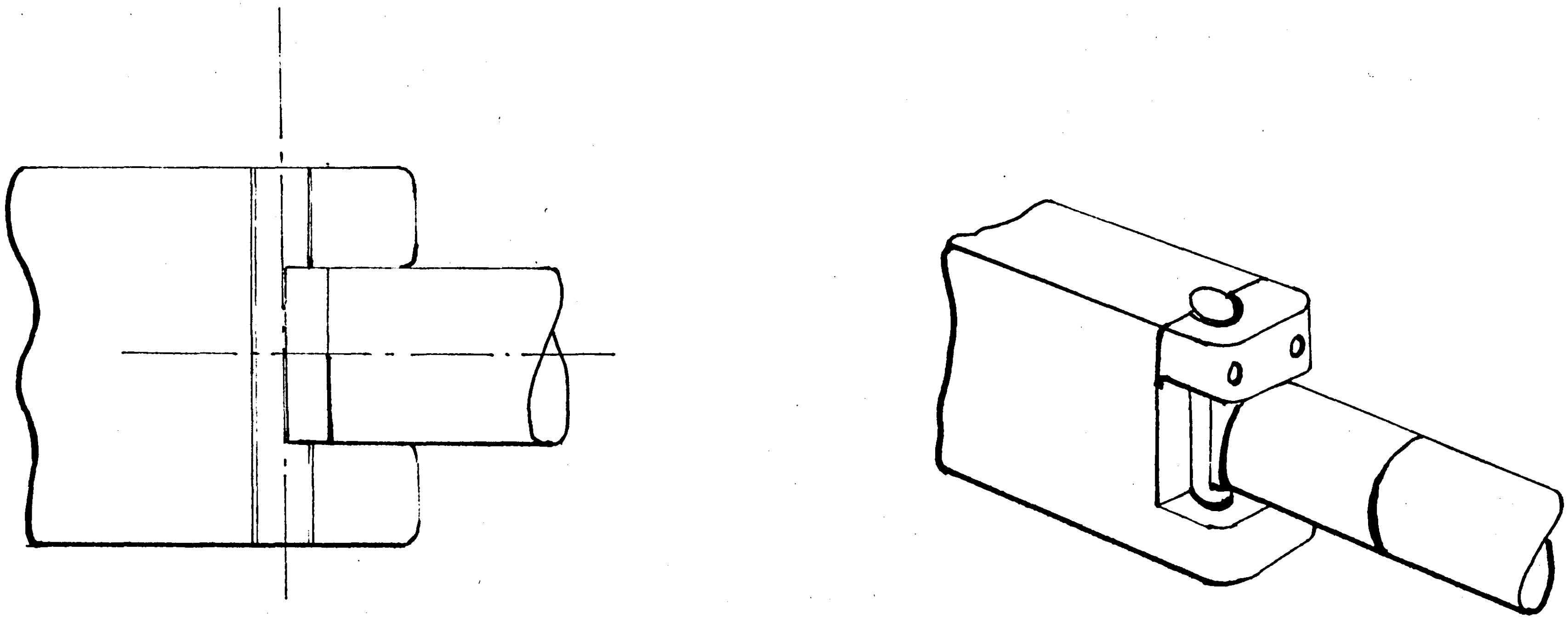
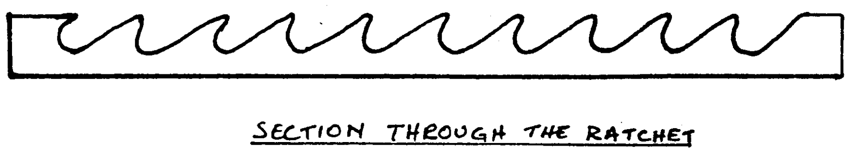


Fig. 152

Carry handle hinge arrangements.



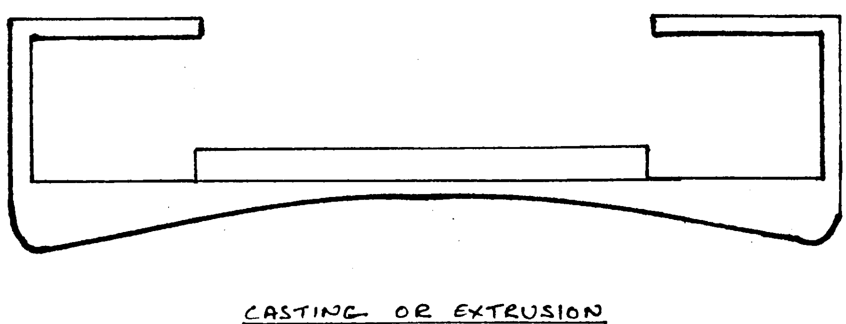


Fig. 153

Backrest ratchet section.

ability to fold inwards. Fig. 152 shows a proposed method of achieving this where the strength is obtained through the bushing that will prevent twisting movement. These units need to be castings but the handle shafts are made from tubular section that only required cutting to length and a plastic handle end fitted to one end. The castings would been to be assembled with the body hinge in the lower frame and the handle shaft hinge in the handle shaft. The hinge components will then be connected by the bushing.

8.2.8 Backrest

There were no real problems affecting the backrest, however, on using this feature it was noticed that the ratchet slipped. This will be easily remedied by altering the shape of the ratchet slots to prevent the pin slipping out without being released. This is demonstrated in fig. 153 which also shows the complete ratchet component as a casting. The spring-loaded ratchet pin and its release mechanism will be assembled from cast components and the supporting base would be made of circular section bent to the correct angles with either cast or moulded nylon hinge ends.

8.2.9 Sub-frame

It was found on testing the trolley, by leaning on the ends that there is an end to end rocking movement. This is the result of spring in the sub-frame allowing movement of the leg system. Should this movement be found to be unacceptable it would be possible to use a channel section to stiffen the sub-frame. This would simplify assembly but add to the weight of the trolley.

8.2.10 General Production Methods

Some production methods have already been suggested in the previous paragraphs. In general the trolley would use extruded section as opposed to drawn tube for all components where this is possible. This would reduce the price of the material as extruded section in three to four times cheaper than drawn material. Where specially shaped components are needed these will be produced as castings, for example, the wheel support units. These would be sand castings though die castings would be recommended if it proves too difficult or expensive to obtain the required standard of finish in the sand castings. The machining process would consist of drilling holes to pre-set measurements and jigs could be used to simplify this operation. There are also some components that contain a slot and would require the use of a milling machine, which would also be required for cleaning up some of the cast components.

8.2.11 Tube bending would be required to form the basic top frame of the trolley and special formers needed to accommodate the flat oval section. The frame would consist of two end sections shaped with the rounded corners and two straight middle sections. The sections would be joined to form the frame by using inserts and joints situated under the wheel support unit castings. These would then be fastened through the frame and insert to form a rigid joint.

8.2.12 Once all the components have been prepared for assembly by pre-drilling, individual sub-assemblies can be made prior to the final assembly of the whole trolley. A typical sub-assembly would be the cross bar with the Trendelenberg release unit and Fowler's position hinge units on it which can be pre-assembled and put in place after the main frame has been made up. After pre-assembly of the sub-groups,the top and backrest frame will form the first unit to be assembled. The legs and sub-frame will then need to be fitted to-

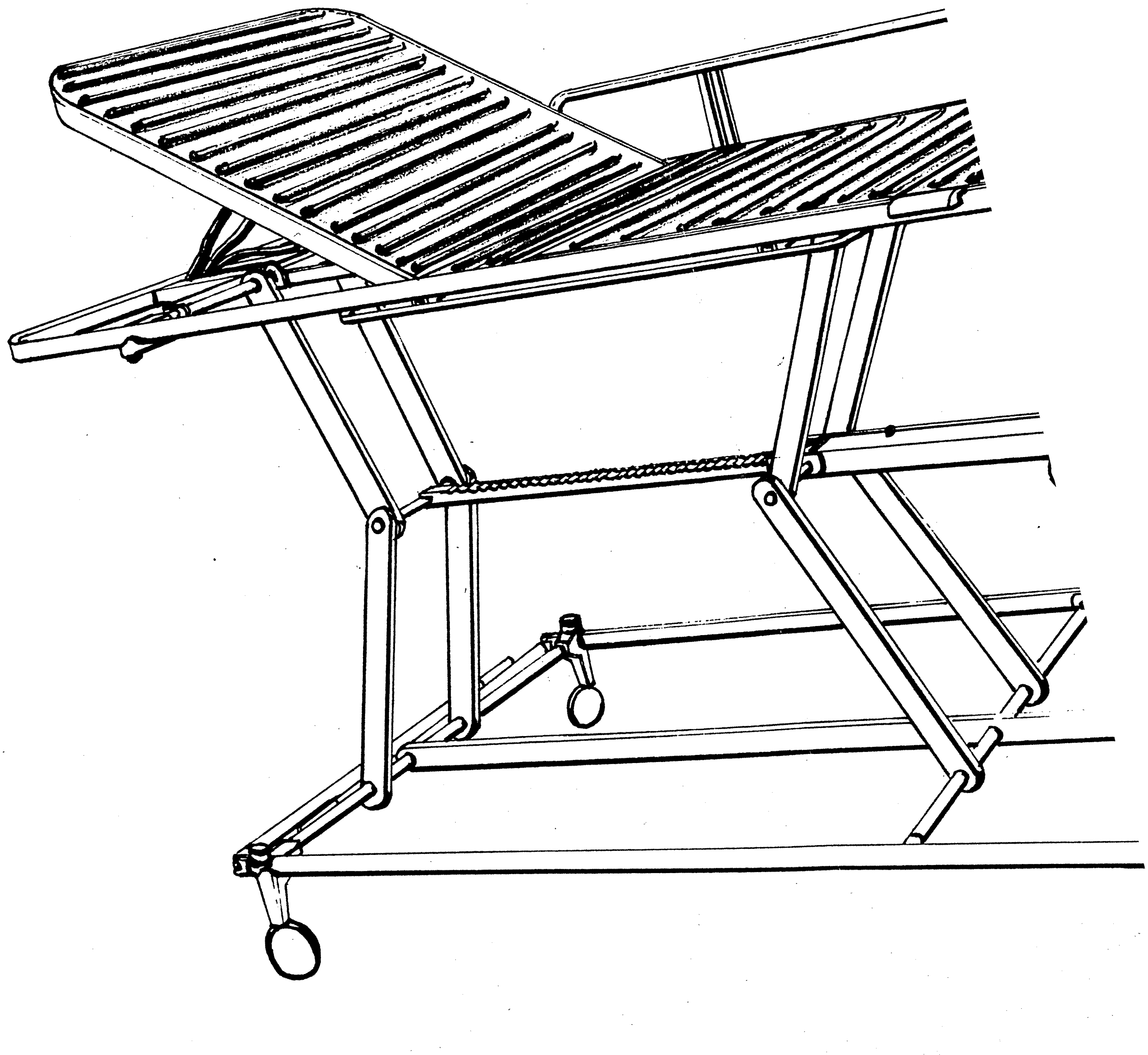


Fig. 154

gether with the cross struts and any components that fit on these such as the Trendelenberg lock units and springs. These and the wheel support unit top castings form the basic framework to which the other parts are fitted. The lower frame can be made up with the carry handle hinges and wheel support castings together with the cross struts onto which the legs have been placed. The central elevating mechanism can then be assembled and the upper and lower frames attached to it. Final assembly would consist of attaching the release cables for the elevating mechanism and backrest ratchet, the wheels and the moulding forming the trolley bed. Fig. 154 shows the fully assembled trolley with the modifications outlined above. During this assembly jigs would be used to locate components and some drilling would be necessary to enable fastenings to be used. Fastening would consist of pop rivets, where there is little strain on a component, and bolts or screws. The cost of materials and this assembly operation is given below.

8.3 Product Costing

8.3.1 Materials

The following is a breakdown of the materials required for one complete trolley. The volumes given are the totals for each set of components required for a single trolley.

Component	Material	Volume cu.mm
Frames	Aluminium BA. 6063 TF Flat oval 20 x 40 x 1.5mm wall thickness x 15.78m	2,335.913

Components	Material	Volume cu.mm
Sub-frame	Al. Flat bar 31.75 x 31.75mm x 3m	571,500
	57.15 x 6.35mm x 350mm	120,015
	44.45 x 6.35mm x 500mm	133,350
Bushings	Nylon 31.75mm Ø x 850mm	
Wheel support castings	Al. casting	560,000
Carry handle hinges - body	Al. casting	308,800.
Carry handle hinges - handle	Al. casting	67,400.28
Carry handles	Al. tube 25.4 x 3mm thickness x 449mm	379,211.74
Trendelenberg release bar	Al. Round solid 12mm dia.x 400mm	48,261.12
Trendelenberg cross pivot casting	Al. casting	47,513.404
Trendelenberg hinge units	Al. flat bar, or Al. casting 6.35 x 31.75 x 400mm	64,757.224
Trendelenberg struts	Al. flat bar or Al. casting 6.35 x 2.54 x 750mm	104,651.25
Cross pivot end/ Trendelenberg lock	Al. casting	22,236.302
Fowler position pivot toggle	Al. unequal angle 38.1 x 12.7 x 3.175 x 1752mm	250,185.6
Fowler position lifting brackets	Al. castings	75,552
Fowler/ Trendelenberg cross pivot	Al. round 16mm diameter	97,417.71
Fowler/ Trendelenberg side brackets	Al. angle or casting	45,408
Fowler/ Trendelenberg pivot holder	Al. casting	32,480

Component	Material	Volume cu.mm
Cross pivots	Al. tube Ø 1905 x 3mm thickness x 1056mm	159,759.38
	Ø 22.225 x 3mm thickness x 1549mm	279,070.16
Top Hat units	Al. casting Ø 16.225 x 2 off Ø 13.05 x 2 off	23,123.846
Fowler position pivot unit	Al. casting	14,700.052
Backrest support	Al. square section 10 x 10 x 535mm	121,400
Backrest slide unit	Al. casting	153,612
Frame bracket	Al. casting	17,084.6
Lower bracket	Al. casting	43,065
Backrest support pivots	Al. casting	7,411.68
Side arm rails	Al. tube Ø 19.05 x 2mm x 1030mm	110,356.45
Side arm lock brackets	Al. casting	18,387.06
Side arm slides	Al. casting	26,948.73
Side arm struts	Al. channel 28.4 x 10mm	226,144.8
Side arm locks	Al. casting	38,768.146
Backrest ratchet unit	Al. casting	78,950.83
Centre unit pivot pins	Steel	155,532.66
Centre unit locking toggles	Steel casting	19,711.8
Centre ratchet bar	Al. casting	115,552
Centre housing	Al. casting	203,304
Trolley bed sheeting		1,119,106

This gives a total volume of material of

8,218,737.2 cu.mm

= 8,218.7372 cu.cm

For BA 6063 Density = 2.70 g/cu.cm

weight of material =

8,218.7372 x 2.70 = 2219059gm

= 22.19059Kg.

Weight of wheels - approximately 2.074Kg/wheel

4 wheels = 8.109Kg.

Therefore total estimated weight of the trolley

= 22.19059 + 8.109 = 30.29959 or

30.3Kg.

8.3.2 Cost of Materials

Cost of aluminium = £1.850/kg (British Alcan)

22.2Kg costs £41.07

Cost of wheels (non-locking) = £7.39 each

4 wheels cost £29.56

Handles, cables, fastenings etc., approx £50.00

Probable total cost of materials

= £120.36

8.3.3 Assembly costs

The following breakdown of the components and the processes needed to prepare them for assembly allows the time required for this operation to be calculated. Similarly, a breakdown of the main assembly process enables the time required here to be assessed. This enables the labour costs to be calculated from the estimated times required to prepare and assemble a single trolley.

a) Assembly preparation

Component	Process	Number off	Time/mins
Sub-frame	Fold	4	10
	Drill holes	8	30
Legs	Drill	24	90
	change tool	3 times	15

Component	Process	Number off	Time/mins
Control unit toggle locks	Drill holes	2	10
Ratchet strut	Drill hole	1	5
	fit & weld pin		10
Wheel support castings	clean holes	12	30
Body hinge unit	Drill holes	4	10
Handle hinge unit	Drill holes	4	10
Trendelenberg cross pivot	Drill holes	2	5
	clean holes	2	5
Trendelenberg hinge	Drill holes	2	5
Trendelenberg struts	Drill holes	4	10
	Change tool	1	5
Fowler position toggle lever	Drill holes	4	10
	change tool	1	5
Fowler position struts	Drill holes	6	15
	Slot	2	15
	Change tool	1	5
Fowler/ Trendelenberg cross pivot	Drill holes	1	8
Side bracket	Drill holes	2	5
Pivot holder	Drill holes	6	15
	change tool	1	5
Backrest support brackets	Drill holes	8	15
Side arm brackets	Drill holes	4	10
Backrest	Drill holes	2	12
		Total	370 mins

Total pre-assembly preparation time = 370 mins

= 6hrs. 10 mins.

b) Main Assemby

	Time/mins
1) Top frame with wheel support units and backrest	45
2) Sub-frame assembly	45
3) Lower frame with wheel support units/ hinge ends	30
4) Central mechanism with release unit	25
5) Leg system/Trendelenberg lock castings/top and bottom frames	60
6) Fowler position cross pivot/ Trendelenberg	35
7) Remainder Fowler position & Trendelenberg position	30
8) Backrest support & slide unit	60
9) Side arms assembly & attach	60
10) Wheel units	15
11) Release levers & cables	45
12) Sheeting	45
	495 mins

	8.25 hrs

Total time for assembly - 495 mins.
= 8 hrs. 15 mins.

Total overall labour time = 8hrs. 15mins
+ 6hrs. 10mins

=14hrs. 25mins.

Assuming labour costs of £5.00/hr.

Cost of labour total = £72.50

Total basic cost of trolley = Labour & materials

= £72.50 + £120.36

= £192.86

8.3.4 It is estimated therefore that the trolley can be manufactured for a basic cost of £200.00 - £250.00 per trolley. These figures are only rough estimates and it may be found that on setting up a production run to prepare and assemble components and sub-assemblies the estimated time may be reduced in turn reducing the labour cost and total manufacturing costs.

9 Discussion and Conclusion

9.1 Introduction

9.1.1 The aim of this project was to develop a new stretcher trolley design after examining existing equipment, particularly the 'York 4' and 'Super 4' models, and to discover any problems relating to these. The information gathered during this process was used to identify problems and to formulate a performance specification against which the new design was created.

9.1.2 The new design was developed through the initial problem solution stages to first prototype/test rig and then to second prototype level. This prototype demonstrates all the working principles for the design solutions to the problems identified and was evaluated against the performance specification and subjected to field trials involving handling exercises. An assessment of this solution followed by an assessment of the methods used to achieve it are given below.

9.2 Design Solution Assessment

9.2.1 When assessed against the performance specification (3.4) the new design compares favourably against the existing models. There are advantages in handling the trolley, particularly access to the operating handles when in the ambulance. There is also increased safety in using the new trolley as all working parts are placed away from handling areas. The benefits to the patient arise from increased security given by side arms. The use of the new elevating mechanism affords greater stability to the trolley than at present and, after testing, should enable the trolley to be used again in the elevated position when wheeling it on reasonable surfaces. As mentioned earlier there are some details on the prototype that caused debate during the handling exercises but these have been revised during the re-design period. On the whole the new design offers greater potential for using all the facilities available both in and out of the ambulance.

9.2.2 The above assessment was based on the performance specification (3.4) which was formulated from the information gathered during the data collection period. Prior to this all trolleys were required to meet the ASAC recommendations (9) which gives a very broad performance/materials specification for a non-elevating stretcher trolley. It also defines certain specific details such as; "the trolley frame should be constructed of lightweight, non-corroding metal", which would have a restricting effect on possible designs. The performance specification developed for this project seeks to define the actions required of the trolley and not the way in which these should be achieved. It has been influenced by the information collected in that it is derived from the processes used during casualty handling and out-patient work. It also differs from the ASAC recommendations in its greater detail based, partly as stated on the processes, and partly on the ergonomic requirements such as specific angles of tilt or elevation. The major difference, however, is that the performance specification is designed around an elevating stretcher trolley and the difficulties peculiar to this such as stability. To date, the elevating trolley has not been specified in any standards though it is becoming more popular in its use.

9.3 Design Methodology Assessment

9.3.1 The development of the design solution starts with the performance specification which in turn was derived from the information collected. During the data collection period information was gathered from a variety of sources and it was necessary to introduce some form of order to enable the relevant information to be separated. This was done by analysing the data and deriving those facts relating either to procedures involving the use of the trolley or to the trolley itself. At this stage it was found necessary to use balloon charts to clarify the relationships between the various facts identified. It was from this that the performance specification was derived. This specification was used as the framework for the design solution.

9.3.2 Ideally a designed product should be seen as a whole unit incorporating all the features within a total concept. In this way it is possible to integrate features into a unit while maintaining an overall image. However, on examining the trolley it was decided that it would not be possible to design all the features simultaneously as the multi-functional use of the trolley was too complex. It was, therefore, decided that the functions should be divided into related groups where possible and designed as units within the whole. This enabled individual solutions to be produced which were then related to the total design concept. It was found necessary, however, to use a priority rating to distinguish those functions that would have the maximum influence on the design solution of the other functions, and to resolve these first in order that the others could be resolved around them.

9.3.3 This method of working had the disadvantage that it was difficult to work on individual units while maintaining an overview of the whole which resulted, on some occasions, in the pursuit of ideas and solutions that were actually unworkable within the context of the others. In some cases this did not become apparent until 3-dimensional work was started. Similarly, some problems could not be resolved until a 3-dimensional structure of the design was available.

9.3.4 The design solutions for these different functions were in most cases generated initially in 2-dimensional form and depending on their complexity some were resolved without 3-dimensional development to final design proposal. Other, however, required early development in 3-dimensional form because of the complex nature of the mechanisms and their relationship to other features within the whole design. As stated above, with some features design solutions were not resolved until the 2nd. prototype had been developed and their position and operation within the context of the total unit could be seen. Two dimensional work was very valuable as a means of examining a range of ideas and layouts but it was found essential to use 3-dimensional mock-ups and prototypes to resolve all the difficulties of the integration of moving parts, the working of the mechanism and position of operating devices. It would be exceedingly difficult to envisage mentally a 3-dimensional solution without a physical product to examine, alter and assess while working.

9.3.5 Undoubtedly, the methods used to develop the design can be improved, although it would be difficult to structure the project in any other way. The main improvement would come with the re-allocation of time to the various stages of the project where problems arose during the present design development.

9,4 Conclusion

9.4.1 At the start of this project the aims were to develop a performance specification, then using that, to develop a design solution for an ambulance stretcher trolley. The first of these aims, the performance specification, was derived from the information search and forms a basis from which any design for an elevating stretcher trolley can be designed. It also enabled problems to be identified relating not only to the existing equipment but to general handling procedures which could be considered during the design solution development.

9.4.2 The second aim, to develop a design solution for an ambulance stretcher trolley, has resulted in the design solution presented in this work and represents the author's solution to the problems identified. These were developed to prototype stage and evaluated during a handling exercise at an ambulance station. The conclusion of this exercise was that the design would be suitable for further development and field trials.

REFERENCES

1 The Oxford Illustrated Dictionary - Oxford University Press and Bay Books Pty., Ltd. Pub. 1978.

2 Encyclopaedia Britannica.

3 Macdonald, R.C; Banks, J.G; Ledingham, I.McA; 'Transport of the Injured' INJURY, 1980, Nov.12. pp 225 - 233

4 Snook, R; 'Ambulances of the past, present and future' RESCUE EMERGENCY CARE, Chap.20 pp 435 - 440 Pub. Heineman, London, 1977. Ed: Easton, K.

5 Department of Health and Social Security Act 1948 - HALSBURY'S STATISTICS OF ENGLAND, Ed. 3, vol. 23 pp 38 - 39; pub. Butterworths, 1970

6 Leas, R.F; 'Ambulance Service', RESCUE EMERGENCY CARE, Chap.18, pp 410 - 411; Pub. Heineman, London, 1977. Ed. Easton, K.

7 Woolham, C.H.M; 'Equipping a Standard Ambulance' BRITISH JOURNAL OF HOSPITAL MEDICINE, May, 1982, vol. 27, No.5. pp.538 - 541.

8 Ministry of Health, Scottish Home and Health Department (1967); 'Report by the Working Party on Ambulance Training and Equipment'; Part 2 - EQUIPMENT & VEHICLES, H.M.S.O, London.

9 Department of Health and Social Security; 'Ambulance Service - Stretcher Trolleys' LHAL 21/71 and Appendix A to LHAL 21/71; 6 July 1971.

10 Rockell, B; 'You'll never find the ideal Ambulance', ST. JOHN REVIEW, 1980, vol. 53, part 2, pp 29 - 30

11 Snook, R; 'The Ambulance' - M.D. thesis, 1972 (?)

12 Interview - Mrs. Mary Hemsley, Industrial Nurse, Redfearn's National Glass. 8 Feb. 1983.

13 Snook, R; Pacifico, R; 'Ambulance Ride: Fixed or Floating Stretchers' BRITISH MEDICAL JOURNAL, 1976, vol. 2, pp 405 - 407

14 Foster, M; Luard, N; 'Floating Stretcher' DESIGN, April 1983, vol. 412, p 5.

15 Wilson, M.J; 'A Third level of Research Methods - Research Styles' Block 1 pt. 1, OPEN UNIVERSITY, Social Sciences.

16 Swift, E; 'A Third Level of Research Methods - Design of Surveys' Block 3, pt. 3, OPEN UNIVERSITY, Social Sciences.

17 Weston, P.A.M; Goodhead, T.C; 'Transfer facilities for the seriously ill and injured' INJURY, 1980, vol.12, part 2, pp 123 - 129

18 Murray, A.M; 'Variable-Height Casualty Patients Trolley' LANCET 1971, April 10. p.737

19 British Standard 896; Part 2, 1965, 'Performance of Stretcher and Stretcher Carriers' par. 2.

20 Dreyfus, H; 'Measure of Man', 1966.

21 Johnson, Ray C; MECHANICAL DESIGN SYNTHESIS Van Nostrand Reinhold, 1971.

The Secretary of State for Social Services has received advice from the Ambulance Service Advisory Committee on stretcher trolleys for the Ambulance Service. The advice is set out in the Appendix and is commended by the Secretary of State to Local Authorities for consideration when ordering additional or replacement stretcher trolleys.

APPENDIX A to LHAL 21/71

STRETCHER TROLLEYS FOR THE AMBULANCE SERVICE

GENERAL REQUIREMENTS

1. The trolley should meet the following general requirements:-

a. It should be capable of use as either a safe and comfortable bed for one reclining patient or a safe and comfortable bench for 4 sitting patients.

b. It should permit ambulance aid, including postural drainage, to be given to the patient.

c. It should be capable of being easily lifted, carried and propelled.

d. It should be capable of use with poles and canvas and be able to carry securely BS (Furley) stretchers.

SPECIFICATIONS

2. Frame

a. The trolley Frame should be constructed of light-weight non-corroding metal.

b. The dimensions of the trolley frame and mattress shall be in accordance with those shown in figure 1 of Appendix B, these are considered essential within this specification. Other dimensions are not given to allow for flexibility in order to achieve other design requirements given in this specification.

c. The weight (including mattress) should not exceed 55lbs.

d. To allow a comfortable ride over uneven surfaces the diameter of the wheels should be 100 mm. The wheels should be mounted in independantly moving castors. Bearings should be of a non-lubricating type. Sprung castors and shock absorbers should not be used as they tend to accentuate vehicle movements.

e. To avoid damage to the ambulance vehicle and walls of buildings and to protect seated patients, the frame should be without projections on either side and the corners should be rounded.

f. The trolley should be equally capable of use on either side of the vehicle, and facing in either direction.

3. Contouring

The top of the trolley should be adjustable in the following ways:-

a. the whole top should be capable of being tilted longitudinally to an angle of 10 to 15 degrees.

b. one-third of the top should be capable of being inclined to form an angle of 60 degrees with the remaining portion.

4. Mattress

The top of the trolley should be covered with a firm mattress of trough-shaped cross-section. The mattress should be cut away in two places on either side to enable ambulance men to grip the frame.

5. Safety of Reclining Patients

Folding guard rails should be fitted on either side, of adequate height to protect recumbent or semi-recumbent patients, both in the vehicle and when being carried or wheeled along the ground. Safety belts should be fitted to the frame of the trolley for the use of recumbent or semi-recumbent patients.

6. Carrying and Pulling Attachments

The trolley should be equipped with pulling handles hinged and of sufficient length to enable an ambulance man trailing it to walk in a reasonably upright posture. Telescopic carrying handles should be fitted at both ends and of sufficient length to allow the ambulance man's body to clear the stretcher when he stoops to raise it.

7. Fittings

The frame should incorporate a device allowing stretcher poles to be clipped to it.

8. Security of the Stretcher Trolley in the vehicle

Foot operated brakes should be fitted diagonally opposite sides of the trolley. The trolley should be so constructed as to be capable of being locked into position at either side of the vehicle. The vehicle locking device should provide 2 locking positions

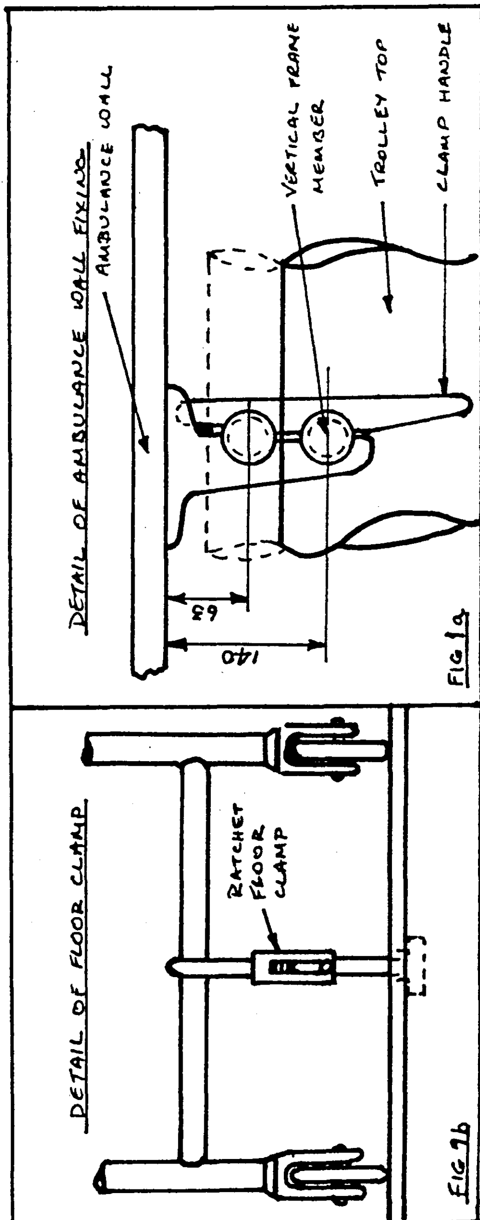
a. close to the wall for use by sitting patients, giving maximum width of gangway.

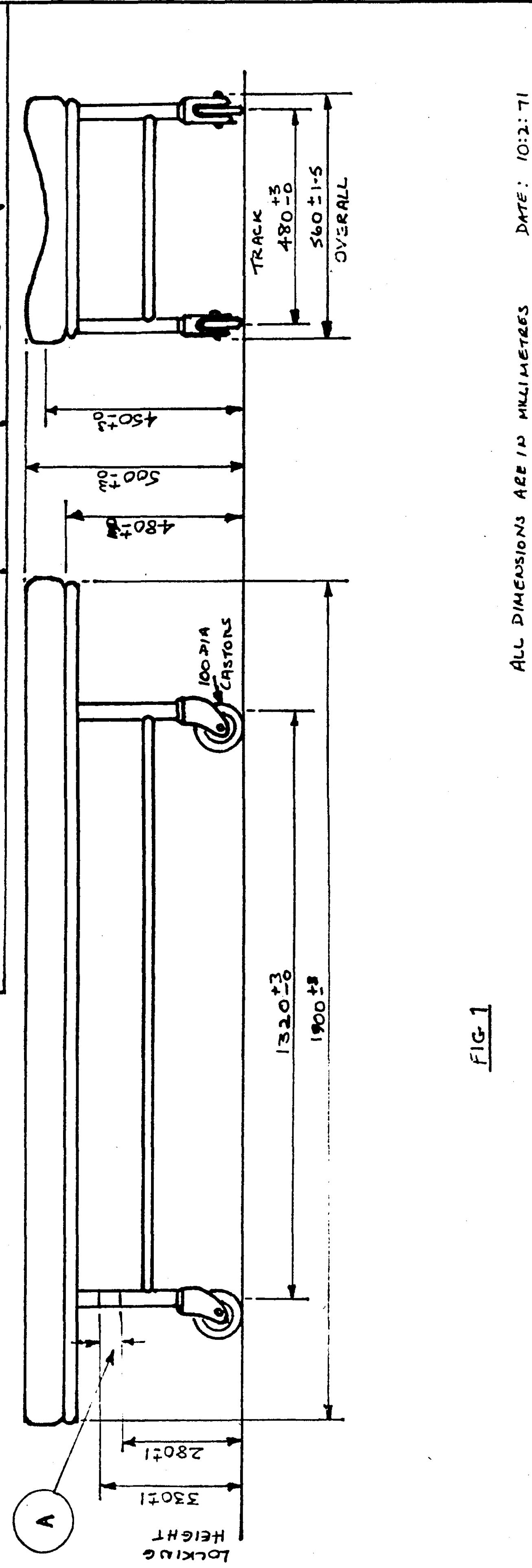
b. away from the wall for use by reclining patient with stretcher poles in place and blankets covering. It should provide positive locking on the wheel vertical support. [See fig 1a of Appendix B]

On occasion there may be a need to position the trolley in the centre of the ambulance. In this situation secure locking can be achieved by providing horizontal supports at the ends of the trolley and the use of floor clamps (See fig 1b of Appendix B). Ambulance authorities may wish to have some of their stretcher type vehicles so fitted.

9. Cleaning

Mattress and frame should be made of materials which can be easily cleaned. Mechanical parts should be impervious to moisture.





NOTES

A DIAMETER OF VERTICAL FRAME MEMBERS TO BE 38±1 IN THIS AREA TO ACCEPT WALL CLAMPS (SEE INSET DETAIL)

ALL DIMENSIONS ARE IN MILLIMETRES DATE: 10:2:71

This visit was arranged with Mr. Tim Rowe, Field Sales Manager, F. W. Equipment Co. Ltd. to enable discussions to be carried out on the use and problems of the elevating stretcher trolleys with the personnel at the ambulance station.

We were able to talk to the officers on standby duty, Cheryl and Paul in the morning and Alan and Alan in the afternoon, and to join the crews in the canteen during their breaks. We were also offered the opportunity of joining crews when answering '999' calls to observe the stretcher trolleys in use.

GENERAL COMMENTS

At this station all ambulances appeared to carry one elevating stretcher trolley, either the 'York 4' or 'Super 4' model, and one non-elevating model (York 2).

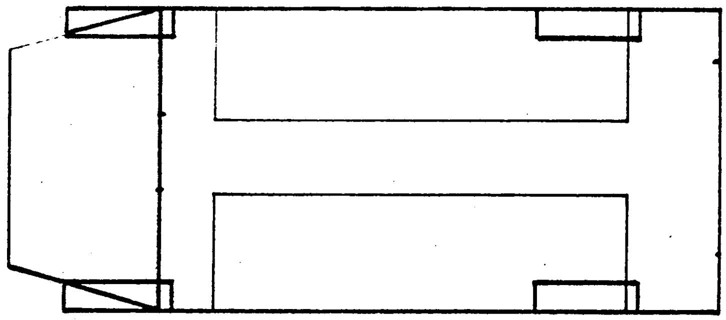
The 'Super 4' always carries the C.P.R. mattress and the 'York 4' the standard mattress. These two are normally used for carrying casualties while the 'York 2' is used as a stretcher only when carrying bodies as this keeps the elevating stretcher clean.

Ambulance layout here differs from that seen at the Ambulance Station A as shown in the diagram overleaf.

These layouts allow a choice of stretcher trolley position mainly depending on team preference when loading the trolley. However, though most teams use the left side, some prefer the casualty on the right or "middle of the road" side (dia.2b) where the trolley lies between wheels and there is less likelyhood of holes and rough patches in the road, so ensuring a smoother ride.

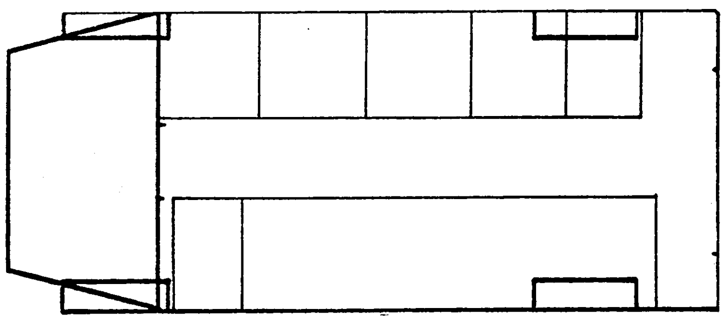
Seating arrangements consist of either four seat units, as shown in dia.2a. or more roomier three seat units (dia.2b). Arm rests and seat belts are provided with the back units. Two attendant's seats are provided in each ambulance, one of which folds up and the other can be removed and clipped onto the side of the trolley.

The vehicles examined ranged from the very new 'Y' registered model to old ones about to be scrapped. The ones travelled in were approximately 3 and 5 years old respectively.



Ambulance Station A Layout

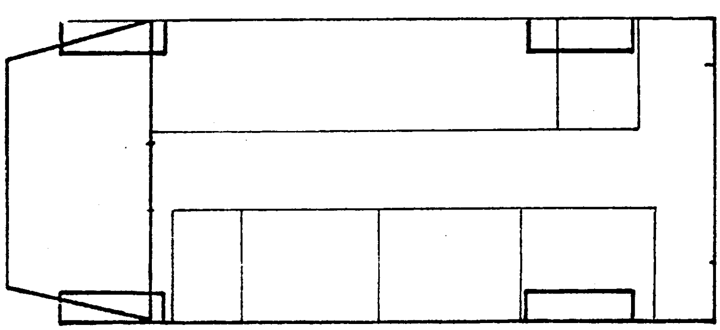
2 stretchers exactly opposite each other and over the wheel arches.



Ambulance Station B Layout

Mornings: elevating stretcher on left (Super 4)

4 seat unit on the right.



Evening: elevating stretcher on the right - (middle of the vehicle) (York 4)

3 seat unit on the left.

In Ambulance Station B, standby duty consists of four hours on with the rest of the shift filled in with outpatient and "geriatric" runs, and at mealtimes any team available in the station answers a standby call.

Most emergency work consists of answering house calls and street accidents and the handling of a casualty is basically the same as described at Ambulance Station A. For a house call the stretcher chair has to be used to fetch the casualty out and into the ambulance where he is transferred to the stretcher trolley. This method is used apparently regardless of the injury though crews say that they have tried to take the trolleys into buildings and up stairs but the corners and size of corridors, and the slope of staircases make carrying a casualty out safely very difficult. Unfortunately, when a person feels ill they automatically retire upstairs to bed.

For a street pick up the stretcher trolley will most likely by used and the casualty is loaded onto the trolley in the street then back into the ambulance.

The trolley is always loaded head first into the ambulance with the casualty facing backwards though in some cases, e.g. a coronary, they would be better facing forwards. Sometimes, if on a long run and the attendant wishes to ride in the cab, the patient is carried facing forward where his face can be observed in the rear-view mirror.

At the hospital, the trolley is off-loaded then elevated before being wheeled into the Accident and Emergency department where the casualty is either lifted or allowed to transfer himself across onto the hopsital trolley.

In the hospital seen the corridors were narrow with sharp corners making access for the trolley difficult and the casualty cubicles were small with either one or two hospital trolleys already in them, leaving little room for lifting and carrying the casualty during transfer.

Though the elevating stretcher trolley is always used for the casualty there is no selection facility to match trolley type with a particular emergency, e.g. an ambulance carrying the 'Super 4' trolley will not be sent to a cardiac arrest case unless it happens to be on duty at the time. Some hospitals, however, do have a special vehicle equipped to answer cardiac calls.

When working at night, the ambulances are fitted with spotlights and they can call on the police for additional help. However, the ambulance officers all carry some form of small pocket torch but would be able to locate any of the controls on the trolley in the dark, if necessary.

When on standby duty, the elevating trolley is always made up with a pillow and blankets and loaded into the ambulance head forward making identification of the ends easy, but Paul feels that should the pillow be removed then he would not immediately be able to identify the head end.

Cheryl, who is 6' tall, has no difficulty in using any of the trolley handles or controls. She has, however, arranged with her partner always to carry the foot or lighter end to prevent injury to herself and the risk of not being able to have children. The comment was made that now the ambulance crews are not allowed into the wards the nurses have to use the trolleys and often do not know how, so that the trolley remainds in its original position. Earlier models had a simple transfer sticker on the side indicating the elevating handle position and operating instructions but this is now ommitted.

Weights to be lifted on the trolleys vary up to 20 stone though some casualties are even heavier. It has also been observed that people are growing bigger and taller.

The officers questioned had not used the hyper-extension facility on the 'Super 4' trolley and therefore could not comment, however, they thought that it would probably take too long to set up and they would tend to use a rolled blanket quickly placed under the casualty's neck to extend it.

Straps with quick release buckles are provided for restraining a casualty but these are not used unless the casualty is violent, such as an epilectic. The plastic mattress can give a static electric shock but this is not enough to worry about.

The stretcher trolleys are normally carried at either side of the ambulance but in some, centre positioning slots are provided where an adjustable ratchet clamp can be used to secure the trolley.

The trolley materials do not appear to be affected by any chemicals used and are easily wiped clean though some slight staining does occur after time. This, however, was not very noticeable. The mattress is also easily cleaned though the fluting in the centre can hold dirt. There is no apparent reason for this fluting other then, perhaps, to make the seat more like a car cushion.

The ambulance officers do not seem to have had any comments from patients on the comfort of or their feelings about a stretcher trolley.

It was suggested that a place on the trolley for a small portable oxygen bottle would be very useful. At present a casualty requiring oxygen uses the ambulance supply while in the ambulance, and the hospital main supply when transferred to the hospietal, but during the transfer he is put onto a small portable supply. As there is no provision for the bottle on the trolley this has to be either tucked into the blanket beside his thighs or placed between the legs which may be embarrasing to the casualty.

PROBLEMS

The following problems were discussed:-

1) Getting a patient out of a house or building especially high rise flats. Attempts have been made to use the trolley but the excessive angle when coming down stairs allows the casualty to slide off the lower end onto the attendant. A 'Scoop' stretcher was tried to lift a casualty off a bed, but this was not found feasible as the bed surface was too soft to allow the stretcher to be slid under the casualty.

2) A casualty 6' tall or over will only just fit on the stretcher trolley and should they have a full leg plaster on with the walking heel fixture, the leg extends several inches beyond the end of the trolley making it difficult to carry them without further injury and in some cases to fit the trolley into the ambulance.

3) The side bars are too low to give a casualty an adequate sense of security particularly if they are big or have large thighs. Older people especially feel the need to hold onto the bars.

4) The position of the towing handles and side bars when loading the ambulance, varies between vehicles but on one it was observed where the side bar had been rubbing the top of the wheel arch. In other cases the side bars will not go in when up, because the back unit is too low. The towing handle can jam on the wheel arch or other fixtures in the vehicle depending on the location of the trolley.

5) Stretcher trolleys have been known to come loose from the locks while the vehicle is in motion upsetting the patient and possibly causing further injury. In one vehicle it was observed that the attendant rode on the stretcher opposite the casualty and kept he foot on the lower bar of the casualty's stretcher to prevent it moving about.

6) The elevating mechanism is frequently used but can be very heavy to operate when lifting a large casualty. Care needs to be taken when lifting as an unequal raise can tilt the trolley and cause it to drop. (This has happened). The slides and ratchet become dirty with grit, bent and worn and can slip allowing the bed to fall with a jolt, or stick in one position so that raising and lowering the stretcher requires excessive force which it is not possible to use with a casualty in place.

7) The backrest is also frequently used but again, can slip when worn giving the casualty a bad shock as it falls backwards. It is sometimes difficult to move smoothly and when in the ambulance, particularly in the position shown in dia.2b., there is very little room for hand access for lifting the backrest.

8) The towing handles get in the way not only when the trolley is in the ambulance

but also while it is being loaded. As the attendant walks up the steps he heels can catch on the handle and in some cases they are removed from the front of the trolley to prevent this.

9) The telescoping handles become badly scored and worn as grit and dirt gets into them. They then become very stiff and need banging to push them back into the lower bar which again jolts the casualty. The caps holding the handles in, are screwed onto the ends of the lower bars and they work loose requiring constant checking to prevent a handle coming out.

10) The telescoping handle ends seem to cause the greatest problems. They are plastic mouldings held in place by one rivet. When the telescoping handle is pushed back into place the handle end hits the cap causing the plastic to split around the rivet and eventually the end will come off. Unfortunately, this always seems to happen when a casualty is either being off-loaded from the ambulance or carried off a field, requiring quick action from the ambulanceman to prevent the trolley capsizing.

F. W. Equipment Co. Ltd., are attempting to solve this problem now by setting a stop within the lower bar that prevents the handle end from touching the cap when the telescoping handle is pushed right in.

11) The Fowler position handle tends to jam against the towing handle when wound fully up. The winding mechanism is sometimes stiff.

12) Lack of maintenance allows parts to wear badly and the aluminium to become scored and embedded with road grit and dust. This in turn leads to excessive wear and stiff or seized movement, however, despite this the trolleys are lasting the life of the ambulance.

COMMENTS - MR. TIM ROWE

The following comments were made by Mr. Tim Rowe on points raised during the visit.

F. W. Equipment Co. Ltd., are now facing the problem that health authorities are cutting back on their expenses and as a result are suggesting that older stretcher trolleys should be re-furbished and re-used in new ambulances. Up to now it appears that when a new ambulance is bought it is fitted with new equipment. However, re-furbishing old trolleys will reduce their sales and a new stretcher trolley model is needed to replace the old one which may then be phased out as obsolete.

The problem of trolleys not fitting in the ambulances is due to lack of liaison between the equipment builders and the coach builders. He has tried to discuss these problems with the coach builders but did not get any response. A result of this lack of communication, however, is that back units are put on at different heights, some of the trolleys will fit under with side bars up but in others if the bars are up the arm rests cannot be used. Similarly, the problem of the towing handle and access to the stretcher in the ambulance is in most cases due to lack of consideration for the users of a trolley.

A similar case arises with the use of the Ferley stretcher which, the recommendations state, should be capable of being fitted over the trolley. It will do so but it cannot then be fitted into the ambulance.

They do recommend regular maintenance of stretcher trolleys and the replacement of worn handles and caps, but this is not always carried out.

He has done some work on a new design for a stretcher trolley, particularly, in considering the use of a hydraulic lift to replace the elevating mechanism, but was unable to find anything of reasonable weight and cost.

1) Ambulance officers - Cheryl and Paul - morning.

A call to attend a collapse case.

This was found to be an eighty year old gentleman suffering from severe pain in his ears and loss of balance, on heart tablets and probably unable to walk very far. He was living in what appeared to be a warden-controlled block of small bungalows and was sitting in an arm chair in the living room.

On arrival Cheryl was dropped off to go and attend to him while the ambulance found the best place to park. Word was sent back to Paul, via the warden, for the equipment that Cheryl needed, consisting of the stretcher chair and a blanket, which he then took round.

The blanket was spread over the stretcher chair and the casualty lifted from his arm chair into it. As there were no steps to negotiate the stretcher chair was easily wheeled out to the waiting ambulance into which it was lifted, with Cheryl at the foot end. The trolley was prepared with the backrest up and the casualty lifted out of the stretcher chair onto it and the side bars put up. Travel in a sitting position was necessary as the casualty complained of difficulty in breathing if lying down.

During the journey to the hospital where he had previously been treated, Cheryl rode with the casualty, sitting on the side of the trolley as she took notes on his condition.

Outside the Accident and Emergency department, the trolley was released and off-loaded with Paul keeping the head end level. (He had to walk bent over to do this). Once on the ground each officer took one end and, using the end lever, elevated the trolley to about waist height and then wheeled it into the hospital.

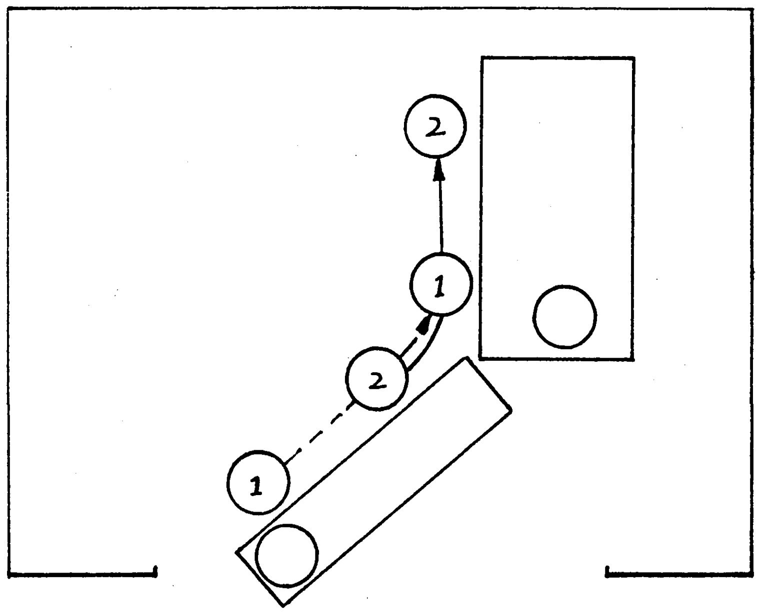
The narrow corridors required some manoeuvring to get the trolley into the casualty cubicle where a hospital trolley was waiting. The trolley heights were already reasonably matched so tha casualty was lifted across onto the hospital trolley.

Trolley positions are shown overleaf.

The patient was signed in by Cheryl while Paul remade the trolley bed and took it back out to the ambulance still at its elevated height so that it could be pushed from its top frame. The trolley was lowered from both ends then re-loaded and we returned to base.

Stretcher trolley used was the 'Super 4' model with C.P.R. mattress.

Casualty build: medium height and weight.


2
1
2
1

2) Ambulance officers - Alan and Alan - afternoon.

Call to attend a diabetic, ill and vomitting.

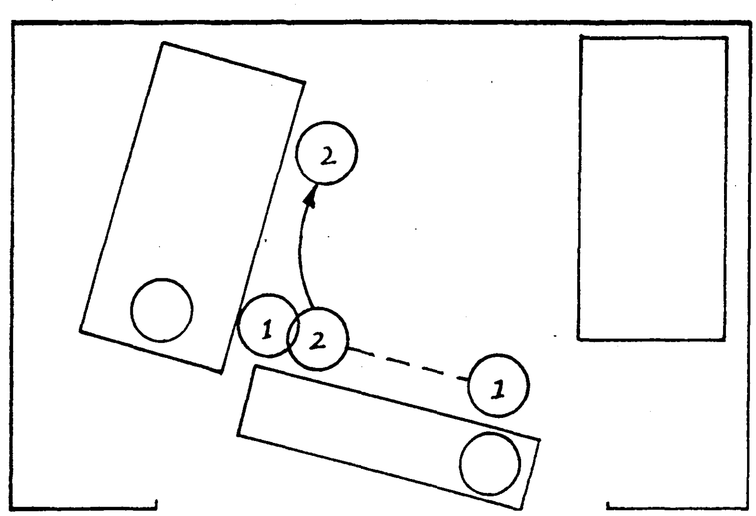
This was found to be a young woman with two young children and a baby, living in a very small dirty house. She had been found by her next door neighbour, outside on the pavement where she had been trying to attract help. She was suffering from confusion and slurred speech and becoming aggressive.

The ambulance was parked outside the house while Alan 2 went inside to attend to the casualty. Alan 1 followed to see what he needed and returned, taking into the house the stretcher chair and blanket. Again the casualty was in a downstairs room so only the door step required negotiating. The chair was lifted into the ambulance and the casualty lifted out and onto the trolley. The backrest was adjusted up to make her comfortable and Alan 2 rode on the opposite stretcher where he could attend to her and make notes. He had to keep his foot on the lower bar of the casualty's trolley as it was very loose in the lock and moving about.

The casualty was again taken to the hospital where she had been a patient only two weeks before with the same problem.

At the hospital, the trolley was off-loaded but Alan 2 preferred to stand up straight when carrying it down the steps so that there was a considerable head to foot tilt for a few minutes.

The trolley was then elevated again from both ends using the end lever, to about waist height and pushed into the department by the top frame. This time there was less room in the cubicle as it contained two hospital trolleys as shown below:-



The casualty was lifted across and the stretcher trolley wheeled back out into the corridor where the bed was remade by Alan 1 before taking it back out to the ambulance. Lowering the trolley was also done from the ends before loading it back into the ambulance.

The patient signed in by Alan 2, we returned to base.

Stretcher trolley used was the 'York 4' model with standard mattress.

Casualty build: small build and light weight.

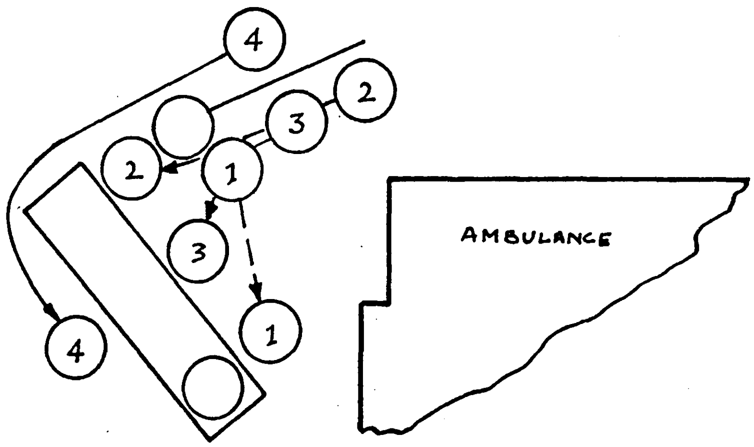
3) Ambulance officers - Alan and Alan - afternoon. (about 10mins. after return from above case)

Call to attend a collapse case on the street.

This was found to be a young woman who had blacked out and fallen hitting her head on the kerb. She had a cut on the back of her head and was slightly shocked. Possibly an epilectic.

The ambulance was able to pull up along side the pavement. At first sight the casualty looked unconscious and Alan 2 jumped out to attend to her while Alan 1 parked the ambulance. She was lying on her side and had been covered with a blanket.

They decided to use the stretcher trolley, so this was unlocked and off-loaded onto the street. Two male bystanders were asked to help lift the casualty onto the stretcher as she was rather large. Loading diagram shown below:-



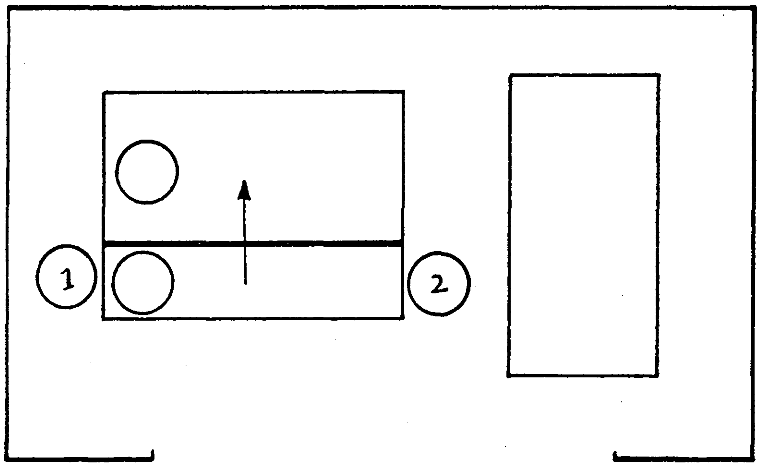
The trolley was then lifted into the ambulance using the telescoping handles. Once again it tilted badly when Alan 2 walked up the steps facing forwards. The trolley was locked into position and Alan 2 again sat on the opposite side to keep the casualty's trolley steady.

During the journey he decided that the casualty would be better sitting up slightly so the backrest was raised with the casualty on it.

She was again taken to the hospital where she had been a patient only the week before.

The stretcher trolley was off-loaded and elevated though this time the casualty was much heavier and the ambulancemen found it more difficult.

In the casualty cubicle it was decided to get the casualty to transfer herself across onto the hospital trolley. The trolley height was adjusted up to match that of the hospital trolley and then steadied by the two Alans while the casualty moved over. Layout is shown below:-



This time, while Alan 2 signed the casualty in, Alan 1 had to find a clean pillowcase as the casualty had been sick. The trolley bed remade, it was taken out to the ambulance, re-loaded and we returned to base.

Stretcher trolley used was the 'York 4' model with standard mattress.

Casualty build: fairly big build and quite heavy.

GENERAL OBSERVATIONS

In all three cases the elevating facility was used and operated from the ends by the end lever which seems to be the more difficult one to use. The trolley was always off-loaded then elevated before being wheeled into the hospital and it was pushed/pulled from the top frame. The telescoping handles were used for carrying it into and out of the ambulance the towing handle did not appear to be used at all.

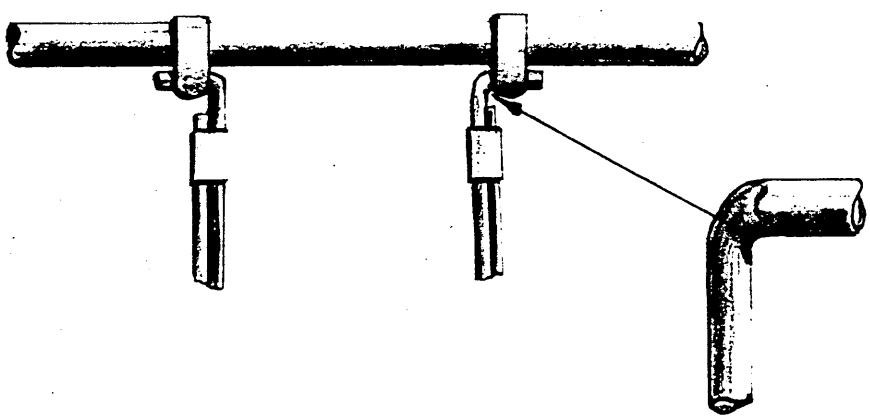
The side bars do not extend much above the mattress and when the casualty is placed in a semi-recumbent position there is no restraint for the upper, heavier part of the body and the casualty tends to sway as the ambulance corners and could probably fall out. It does not look secure and in the last case the bars were definitely not big enough to have prevented the young woman from falling out if the ambulance had swerved.

The side bars cause a dent in the lower bars where they rub when they are down. The lower bars also become damaged by being used as a foot rest. This was pointed out by Mr. Tim Rowe who also said that castings were now being used with a stop that will prevent this.

When being lifted the trolley showed considerable flexing and there was some concern about the telescoping handles bending and possibly breaking.

One stretcher trolley examined, (ambulance registered 1978), showed considerable wear at all the moving parts. The lift was badly worn and tended to tilt to one side (left) when up. This was Cheryl's vehicle and the trolley is used on the right so this could be due to her riding on the trolley with the casualty.

The telescoping handles were very stiff and the ends had been re-rivetted on. The towing handle at the front had been removed and the one at the foot had worn badly as shown below:-



The end lever for the elevating mechanism was bent and had been badly scored by the screw which operates the Fowler position. This screw was very stiff.

There was no observed wear to the wheel units though apparently this can occur.

Wear in this stretcher trolley appeared to be general and all joints were loose.

An old model of the stretcher trolley was seen where, when the backrest was raised, the end could be telescoped in to shorten the length. The problem with this, however, was the wheels were nearer the centre and the trolley overbalanced when the end seats were used.

SUMMARY

The main problems that seemed to concern the ambulance officers at this station were:-

1) Getting a casualty out of a building, particularly from an upstairs room.

2) The handle ends coming off and the telescoping handles bending.

3) The towing handles getting in the way and becoming bent.

4) The backrest lever slipping and lack of room to use it in the ambulance.

5) General wear and lack of maintenance causing stiff movements and making the trolleys difficult to operate.

There were no comments on the use of the 'Trendelenberg' position.

In the stretcher trolleys seen all the facilities provided, except the hyper-extension, were very well used.

This visit was extremely interesting and has provided very useful information.

Sara L. Cox
21 December 1982.

APPENDIX B1

Information from the diary of ambulance officer Alan 2.

AMBULANCE STATION B.

It is the second largest service outside London and covers 416 square miles.

Approximately 464 emergency calls are received and 3828 outpatients taken to hospital daily.

The population served is 2,718,100.

The total number of patients carried and miles travelled for 1980.

Total number of patients carried	1,126,653
Including emergency cases	127,119
Urgent cases	42,420
Planned cases	867,738
Agency and other	89,089
Rail (to and from station)	286
Total mileage	5,646, 627

STATEMENT OF ADVANCED STUDIES UNDERTAKEN BY CANDIDATE DURING PERIOD OF RESEARCH

1 BSc.3 Lectures on Mechanism Design by G. Cockerham in the Mechanical & Production Engineering Dept.
4 lectures of 3hrs duration at Sheffield City Polytechnic, January, 1983.

2 Modular Preparatory Course in Health Studies Research, Level 2 - Course Leader Dr. V. Reed, Personal tutor Mr. J. Mitchell.
10 - 1 day sessions in the Department of Health Studies, Sheffield City Polytechnic, April - July 1983.

3 Modular Preparatory Course in Health Studies Research, Level 3 Course Leader Dr. N. Malin, Personal tutor Mr. J. Mitchell.
5 - 3hr sessions in the Department of Health Studies. Sheffield City Polytechnic, October 1983 - June 1984.