DESIGN PROBLEMS ASSOCIATED WITH CAPSULES

Since this subject is entirely too broad for the limited time that has been allocated, it will be discussed in detail only as to those problems affecting the configuration and the weight of the capsule. However, before problems of an individual capsule can be analyzed along any lines, the design thinking must be accomplished to establish the type of capsule required. Many things influence such a decision. However, the same problems will affect the design of the specific capsule once the type has been chosen. The following is a list of such items:

1. Size of airplane and space that can be allotted to the capsule and cockpit.
2. Type of aircraft.
3. Location of cockpit or station in the aircraft.
4. Performance of the aircraft for which the capsule is designed.
5. Type of ejection that is desired.
6. The propulsion or ejection method.
7. Visibility required.
8. Method of entrance to the aircraft.
9. Cockpit accessibility required.
10. Pilot comfort.
11. C.G. and weight requirements both of the aircraft and that which will be designed into the capsule itself.
12. Configuration of capsule.

The types of capsule from which a choice can be made are arbitrarily classified for the purpose of this paper as:

1. Nose or tail cone capsule - the fore or aft extremities of the aircraft which might be blown off or catapulted.

2. Cockpit capsule - that type of capsule which incorporates all of the cockpit equipment.

3. Pilot's pod - the type of capsule which encloses the pilot only in a minimum of space.

4. Combination type capsule - this is the type which incorporates more cockpit equipment than the pilot's pod but less than the cockpit capsule. For example this type capsule might include flight controls but not consoles or instrument panels.

Some of the more evident advantages and disadvantages of utilizing these different type capsules are:

I. Cockpit Capsule

Some of the advantages of this type might be:

1. Possibility of obtaining a more integral cockpit design with consoles, instrument panels and controls incorporated in the capsule and thus maintaining good accessibility.

2. Possibility of incorporating such items of equipment as communication radio that may be highly desirable particularly on long range aircraft.

3. With space not at a premium there lies a possibility of better streamlining and the incorporation of fins for stability during ejection.

4. Also there is the advantage of having more freedom in positioning the c.g. by locating the equipment judiciously within this larger capsule.

Items that may prove disadvantageous to the designer of this type of capsule are:

1. The space it requires in the aircraft.

2. The cockpit standardization program which has standardized the cockpit dimensions as well as cockpit console sizes prove a disadvantage here in that it does not lend itself to the most compact design. A program of miniaturization of cockpit controls would aid this design greatly.

3. The problem of acquiring sufficient density, to compensate for the greater drag, and necessary to maintain proper decelerating g's upon ejection may be difficult to overcome.

4. The problem of obtaining an ejector or catapult to accommodate the greater weight is present.

II Pilot's Pod

Some of the advantages of this type of capsule are:

1. The small space it may require and the possibility of obtaining low weight.

2. It has particular advantage in standardization for crew members on multi-placed airplanes.

The disadvantages may be:

1. The pilot or crew member will probably have to retract his arms or legs upon ejection in order to accommodate the smallest capsule possible.

2. The problem of incorporating sufficient weight to stay within the pilot 'g' limitations on high speed airplanes may be difficult to solve.

3. There is the problem of providing the crew members the necessary controls within easy arm reach and yet have them outside of the capsule upon ejection.

4. If the pod is intended to be used as an exposure protection for ground survival providing sufficient space to accommodate the occupant in a non-cramped position may be difficult.

5. The problem of providing sufficient space to accommodate the necessary survival equipment will have to be over come.

III Nose and Tail Cone Capsule

When crew compartments are located at the extremities of the aircraft the designer has a tendency to be influenced towards the nose or tail cone capsule. However, in the case of the nose capsule the problem of separation and stabilization after separation of this body

on high speed aircraft presents definite limitations to this method.

IV The Combination Type Capsule

The combination type capsule embodies, as would be expected, some of the advantages and some of the disadvantages of both the cockpit capsule and the pilot's pod. It is a compromise in cockpit accessibility, pilot's comfort, weight and space requirements and many of the abovementioned items.

Once the type of capsule has been selected the next step is the designing of the specific capsule. The problems encountered in choosing the type of capsule will again be found in the design of the specific capsule. However, they can be divided into two basic categories.

1. Basic safety problems - those incurred in all capsule designs.
2. Special operational problems - those incurred due to specific installation requirements in a particular aircraft.

Under basic safety problems we have such items as:

1. Weight and C. G. Location.
2. Shape and configuration.
3. Stabilization problems.
4. Method of descent problems consisting of parachute size, sequence of operation, etc.
5. Capsule structural problems such as pressure seals, strength, internal clearances, materials of construction and methods of manufacture.
6. Ground survival problems.

Under special operational problems such things may be listed as:

1. Method of entrance to aircraft.
2. Methods of ejection that can be provided.
3. Pilot's comfort.
4. Cockpit size and accessibility.
5. Visibility.
6. Detailed problems covering equipment installation involving cockpit controls, flight controls, seat, survival equipment, oxygen and anti-G suit equipment, disconnects and ejection mechanism.

Of course, it is readily seen that all items necessarily will be reflected and could be classified under safety. Safety presents the most basic problem and the one most difficult to solve. With the amount of design thinking that is required for such an item as the capsule, it is absolutely necessary that it be fool-proof and embody all the items necessary for safe escape. Since, as previously mentioned, the allotted time is not nearly sufficient to go into the details of the various problems, this paper will discuss only the first two items; namely, weight and c.g. location, and size and configuration. The other items will be discussed only as they affect these two.

1. Weight and C.G. Location

This is a serious problem and it is affected directly by most of the above list of items. The answers to the others being monitored by the necessary answers required by the weight and c.g. location in the capsule. The 'g' limitations on the human body will determine,

along with the maximum Mach number that may be encountered during the ejection, the weight that will have to be provided.

Figure 1 indicates weight vs Mach number for an assumed capsule with an assumed 'g', established and maintained. It shows, for instance, that if ejected at a Mach 1.2 at 20,000 ft., in order to maintain an assumed momentary 35 'g' limitation, the weight would have to be 310 lbs. However, if the speed was increased to Mach 2 at this altitude to maintain the same 'g' the weight would have to be increased to 910 lbs. High speed ejection is not the only thing that determines the weight, however, since some of the items that 'ride herd' on the designer to keep him from adding too much weight are such things as: the type of ejection that can be accommodated, the weight permitted by the aircraft, the c.g. location of the aircraft and the volume of the capsule permitted by the aircraft.

The increased weight of the capsule may have a detrimental affect on the minimum altitude where safe ejection can be accomplished. The seriousness of this depends a great deal on the attitude of the airplane when ejection is attempted. Trajectory is another item that must be taken into account when establishing the final weight. Clearances with the aircraft on upward ejection may be adversely affected by the increased weight while downward ejection is, of course, somewhat benefited.

Increased weight also is a disadvantage in solving the water survival problem. If the capsule is designed for floatations not only the limit of weight is important but the location of that weight is very important.

The C.G. Location controls the stability of the body. It is normally

very important to try to obtain the lowest C.G. possible, both for stability during ejection as well as in the water. Any adequate C.G. for the former can be obtained by the proper location of equipment within the capsule such as batteries, flight controls, armor plate, etc.

A solution to the problem of stability in water is undoubtedly a keel. Much thought should be given to the problems that confront the designer in making the capsule seaworthy. Such things as the structure should be designed to withstand the water impact without opening any seals. The overall C.G. location should be such as to permit the pilot to stay in the floating capsule in a comfortable position. To obtain the proper center of gravity - center of bouyancy relationship, an extendable keel with as much heavy equipment as possible may have to be utilized.

2. Size and Configuration

This item is monitored by many of the above listed problems and they will be discussed below to show their direct effect of this item. However, basically it is again determined by the crew's physical limitations. The 'g' limitations of the pilot points toward having the minimum drag body that can be obtained for high speed ejection.

The weight has been discussed previously and affects the size and configuration of the capsule only in that sufficient space must be provided to accommodate the necessary weight to maintain the proper 'g's. Fig. 2 shows the capsule width plotted against weight. This assumes the same coefficient of drag and the same general body shape but with the width varied. The curve indicates that if the drag area of the capsule is increased, the amount of weight that is required to

maintain a specific 'g' limitation under the same altitude airspeed conditions. For instance, if the width of the given capsule is 27" the weight would have to be 550 lbs. if ejected at Mach 2.2. If the capsule is increased to 42 inches in width the weight would have to be 840 lbs. for the same speed. At Mach 3 the weight for a 27" capsule would have to be 940 lbs., while for a 42 inch capsule it would have to be 1,440 lbs. An example of how the weight affects the size and configuration is as follows: A minimum capsule width of say 27 inches (not sufficient to include consoles) if increased to 42 inches which could include the consoles, would necessitate additional weight of 290 lbs. in order to maintain the same 'g's if ejected at Mach 2.2 at the illustrated altitude. Estimated normal console weight (panels plus piping and wiring), predicated upon present day single place fighters will run approximately 110 lbs., which is considerably under what is required. Since it is doubtful that the structure of the capsule would make up this difference if the width only was increased, it would probably mean the length would have to be increased in order to accommodate necessary equipment required to obtain the desired weight. This evaluation does not take into account the changes of shape that may be made on the larger capsule to reduce the drag coefficient.

3. Stabilization

This problem will not be discussed in any detail here except to state that undoubtedly the configuration of many capsules will have to be modified to enable the installation of fins.

4. Problems - Methods of Descent

This is another item that has many features other than those that affect weight and configuration. However, the weight of the capsule, the allowable descent velocity (determined by the maximum stopping distance that can be assumed, and the allowable 'g's that the human can withstand) will determine the size of the main canopy. The volume of the main canopy plus the volume of the risers and the volume of the drogue chute must be accommodated in a capsule in a location and arrangement that will allow proper release.

5. Structural Requirements

The shape and configuration will undoubtedly be governed at least limitedly by the materials from which it is to be made, the method by which it can be manufactured as well as the operational requirements which will be dictated by wind blast, landing loads, (both on land and in water) crash loads, and normal flight operation requirements. The flight requirements will require a clean internal configuration to prevent injury to the pilot.

Problems of providing sufficient strength for pressurization of the capsule and adequate sealing of the doors will also affect the configuration.

6. Ground Survival

The problem of ground survival will also be reflected in the weight and configuration of the capsule. It means little to save the

man in the air if he is to perish on the ground or in the water. This means that certain problems present themselves. The capsule, depending on location of operation may have to provide protection from exposure in the arctic regions. This may affect the material from which the capsule is constructed. Since a material of a low heat transfer coefficient is desireable, some heating provisions may have to be made. Even the cockpit cooling problem also may have an effect upon the configuration since on high speed aircraft it may be necessary to direct the cooling air within the capsule or pod.

7. Visibility

This influences the configuration greatly as it can be readily seen that in the case of canopy type aircraft the contour of the capsule would have to be designed to fit within this canopy without any loss of visibility. This might be accomplished by incorporating the canopy as part of the capsule. Other crew stations present their own problems of visibility both from the standpoint of viewing equipment and controls within the airplane as well as obtaining the necessary outside vision.

8. Method of Entrance to the Aircraft, Direction of Ejection and Type of Propulsion

These items all go hand in hand and provide difficult problems that must be solved and will definitely be reflected in the final weight and configuration of the capsule.

9. Pilot's Comfort

This point is very important in its effect upon the weight,

shape and size of the capsule. It is possibly more important on long range aircraft due to the problem of fatigue encountered. However, the problem in high speed interceptors requiring quick operation by the pilot, necessitates that the pilot be in a non-cramped position. Also, as in the case of many new items (it was true in the case of the ejection seat) there may be a psychological problem of convincing the pilot that an airplane equipped with such a device as the capsule is a safe one. Pilot comfort will go a long way in this sales program. A great aid in acquiring pilot comfort in capsule design comes in the possibility of eliminating much of the highly cumbersome equipment that has gradually become attached to the pilot in the last few years, such as the parachute, life raft, exposure suit, etc. These items by judicious design may now be a thing of the past.

10. Required Cockpit Accessibility

This item will have a great influence on the shape and configuration of the capsule. As the aircraft goes faster and higher, pilot controls have to be made more accessible, easier to manipulate and more distinctive in location and operation. The pilot's time constant is getting smaller. There is considerable talk of the pilot's days being numbered and some of the old timers of that sect, on hearing about some of the things proposed for future aircraft may be glad of it. However, that point of progress, be it such, is yet to come and at least in the immediate foreseeable future the pilot is very much a part of the program, as shown by such requirements as the capsule. The indications are he will be a much busier man than ever before despite advances

in automatic equipment. An example of increased cockpit complexity can be obtained by comparison of the F-84 cockpit and the proposed cockpit for the XF-103 airplane. Considering console panels only, the F-84 has 12 control panels consisting of approximately 50 switches and knobs, while the XF-103 consoles have 34 distinct control panels consisting of approximately 113 knobs and switches. Considering the different speeds of the two airplanes the necessity of requiring improved accessibility is immediately evident, and, therefore, any capsule configuration for this type airplane has to be designed with this in mind. In the case of the combination capsule and pilot's pod this item will contribute greatly to the design of the door, the pressure seals and surrounding structure to be utilized.

11. Equipment Installation

This item definitely affects the size and configuration as well as the weight. The amount of equipment to be provided has to be ascertained beforehand. Such things as survival equipment and the amount of aircraft equipment to be included in the capsule will be predicated on the weight and size of the capsule that can be permitted by the specific aircraft. Flight controls require sufficient space to obtain full movement of the stick and rudder pedals if incorporated within the capsule. Special provisions will have to be made to either move the controls to and from the pilot or move the pilot to and from the controls, if these controls are not incorporated within the capsule. Other items such as the seat, instrument panel, consoles, oxygen system, disconnects and ejection mechanism will all have a bearing on the final weight and configuration.

How specific problems encountered in the design of a capsule for a particular aircraft affects the design may be illustrated by discussing some of the problems encountered in the design of the capsule now being worked on at Republic Aviation Corp. Much of the thinking is not finalized on this capsule as yet and some design changes may be made as a result of final information from such sources as wind tunnel tests, floatation tests, etc. This capsule is a combination type capsule in that it incorporates the aircraft flight controls but does not include the consoles and instrument panels. Specific problems that arose in the design for this particular aircraft originated mainly from the type of entrance that was utilized. Due to the fact that this aircraft is an interceptor type, it was felt that quick entrance was of the utmost importance. The quickest type of entrance that could be accomplished was through the bottom, utilizing the capsule as an elevator.

Figure 3 shows the capsule in the ground egress position. This feature compromised the disconnect design and was the contributing factor in the decision to use downward ejection. The rails are telescoping and are used for ground entrance as well as ejection. Disconnects required for normal ejection are usually designed to be used once without consideration for re-engagement. In this installation they must not only be disengaged, but must be satisfactorily re-engaged after ground entrance.

The following items are the main things that require disengagement:

1. Ventilation and heating ducts.
2. Anti-G suit line.

3. Flight controls.

4. Winch cables (ejection only).

5. Electrical connectors for microphone, throttle beep switch, dive brake switch, trim switch, trigger switch and automatic pilot release.

All the flight controls will be taken out of the capsule in a spline-type joint. The disconnect was made difficult by the fact that all the cockpit controls must be locked in place when disengaged for normal egress from the cockpit on the ground. Since the aircraft utilizes boost controls and they are, therefore, irreversible, proper re-engagement is assured. The control linkage will run under a false floor under the seat to the aft end of the capsule where thisspline-type joint is located.

Due to the complexity of the XF-103 cockpit as was indicated previously, much effort went into adapting a capsule for maximum comfort and control accessibility. (Figure 4 shows the overall dimension of the capsule. A standard seat with standard adjustment has been incorporated). This seat will incorporate a standard lap belt, shoulder straps as well as body restraining means such as shoulder blocks and head clamp if required. Shoulder blocks or some type of upward restraining means are very important in this design since instead of moving away from the canopy or surfaces above the pilot's head that surface also moves downward.

Sufficient oxygen had to be provided for high altitude ejection. The oxygen system is completely incorporated within the capsule consisting of two type D-2 oxygen bottles, a type D-1 regulator and the required check valves. A filler valve is located for easy ground maintenance at the rear of the capsule. This supply will be utilized in flight as well as ejection

and deletes the need for a disconnect in this system.

Adequate provisions of recovery equipment had to be provided. Provisions have been made to assure a safe descent both on land or water. A descent velocity of 24 ft. per second was chosen since this velocity would give approximately 12 'g's on landing considering a stopping distance of approximately 9 inches and a maximum rate of application not more than 200 'g's per second. With the nose section designed to permit some crushing without fracture, plus the fact it is anticipated that the capsule will first land on the nose cap then fall back on the keel, deceleration over an appreciable distance is obtained. A 33 ft. diameter parachute of the guide surface type is used for the main canopy. An altitude-drogue force device prevents the main chute from being deployed until the capsule has descended to an altitude of 15,000 ft., and an airspeed no greater than 350 miles per hour has been reached. The deployment of the main canopy, controls the keel release allowing the keel to be extended, thus obtaining the stability in the water as well as the absorption of a great detail of shock when descending on land.

A 7/8 inch fibreglass sandwich construction appears to be satisfactory as far as strength is concerned. The seal around the doors are to be a rubber canopy-type seal pressurized by a bottle located in the keel. This pressure seal must not only maintain a differential pressure of 5 lbs. per sq. inch throughout.the low pressure regions of high altitude, but in the case of this particular capsule must provide a water seal also, since the floatation line is above the seal line. The capsule will be able to be pressurized independently of the cockpit. This may have an advantage in case of cockpit pressure loss. The capsule could be closed and descent

be made to a safe altitude by means of incorporating within the capsule in addition to the flight controls certain switches such as a throttle and dive brake beep switch wired in parallel to the main controls.

Another, but by no means the least difficult problem in this specific design has been the ejection control. This control is necessarily required to be placed so as to be:

1. Easily reached.
2. Adaptable to good leverage for the pilot operation with minimum effort.
3. Not in the way of normal cockpit operation.
4. Adaptable in design to accommodate the given and various functions that must be performed.

The following is a list of various items that this ejection control must accomplish. It might be well to state here that it is felt that these functions should be accomplished by direct mechanical methods and that squibs and explosives of that sort should not be relied upon. The ejection control under consideration at the present would be similar to that on some of the present ejection seats, in that it first requires a guard to be pulled, then a trigger to be squeezed. The movement of the guard handle will:

1. Lock the shoulder straps.
2. Release the shoulder blocks.
3. Position the head restraining unit.
4. Pull the pins in the bottom door.

5. Release the fairing on the bottom of the capsule (this is to reduce the drag area).

6. Arm the catapult.

7. Release the winch cables.

8. Close the capsule door.

9. Inflate the door seal.

10. Release and position the trigger.

11. Release stops on the rails.

Upon squeezing the trigger handle the catapult is fired. This in turn will release the fins, if required, upon leaving the rails.

The above mentioned items were only glossed over and were not gone into in any detail but have been mentioned solely as points to indicate the type of problems that the capsule designer encounters. Some can be handled easily, some provide quite a stumbling block. However, since once it is decided a capsule is required, it cost little more to assure that it is absolutely fool-proof, so no problem should be considered solved without having safety as the major reason behind the solution.

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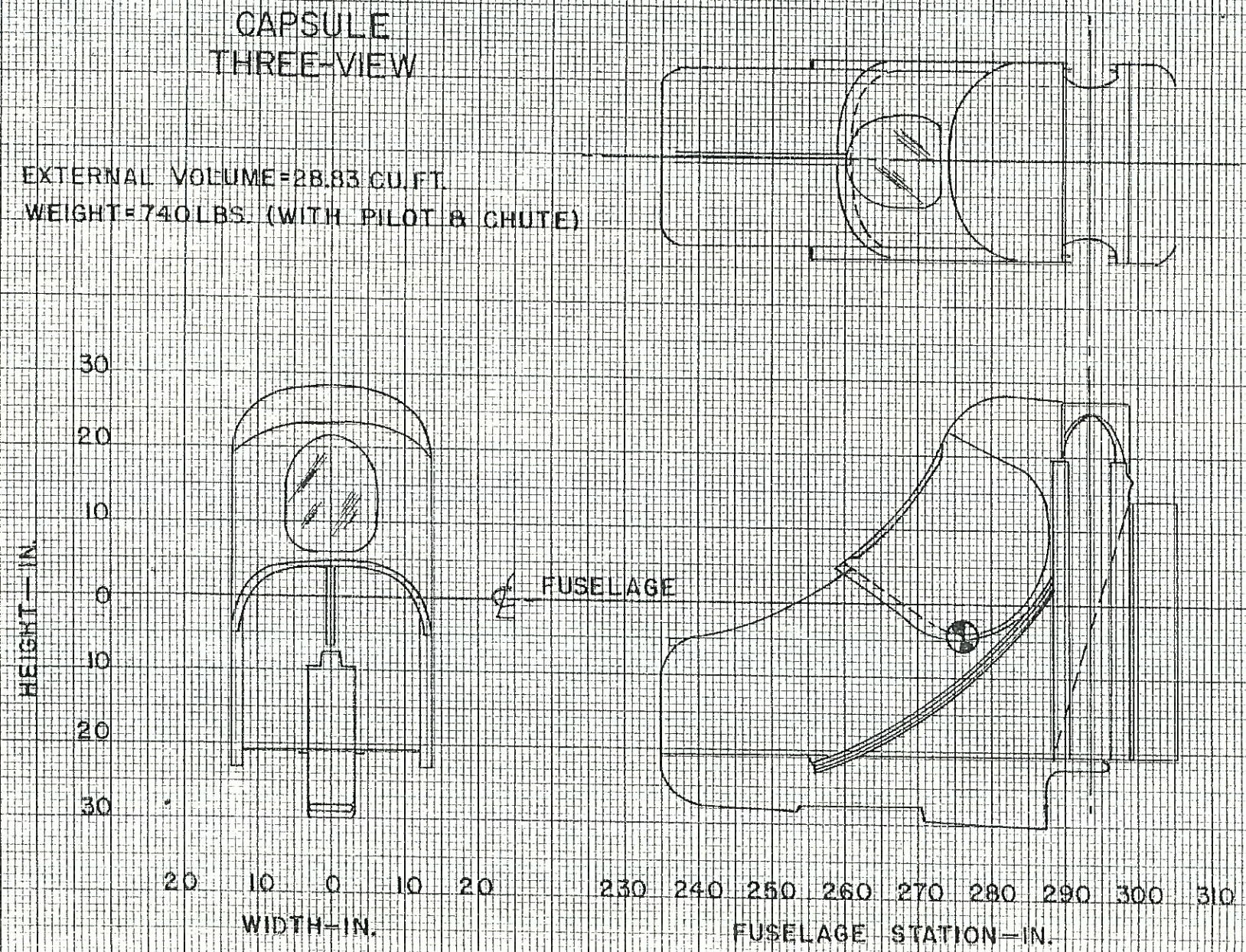
XF-103

CAPSULE THREE-VIEW

EXTERNAL VOLUME=28.83 CU.FT.
WEIGHT=740 LBS. (WITH PILOT & CHUTE)



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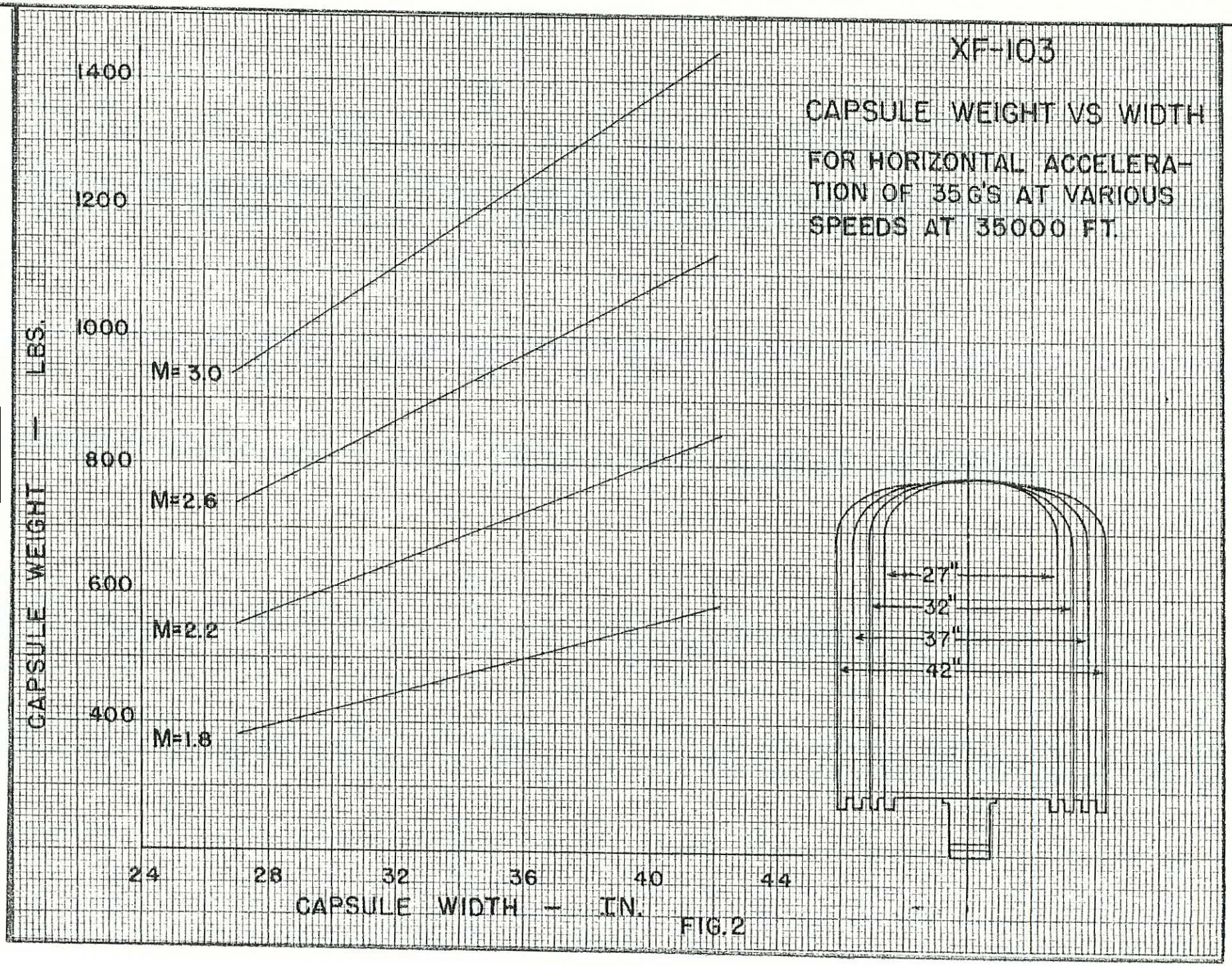

FIG. 2

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CAPSULE WEIGHT VS MACH NO. AT VARIOUS ALTITUDES FOR HORIZONTAL ACCELERATION=35G'S

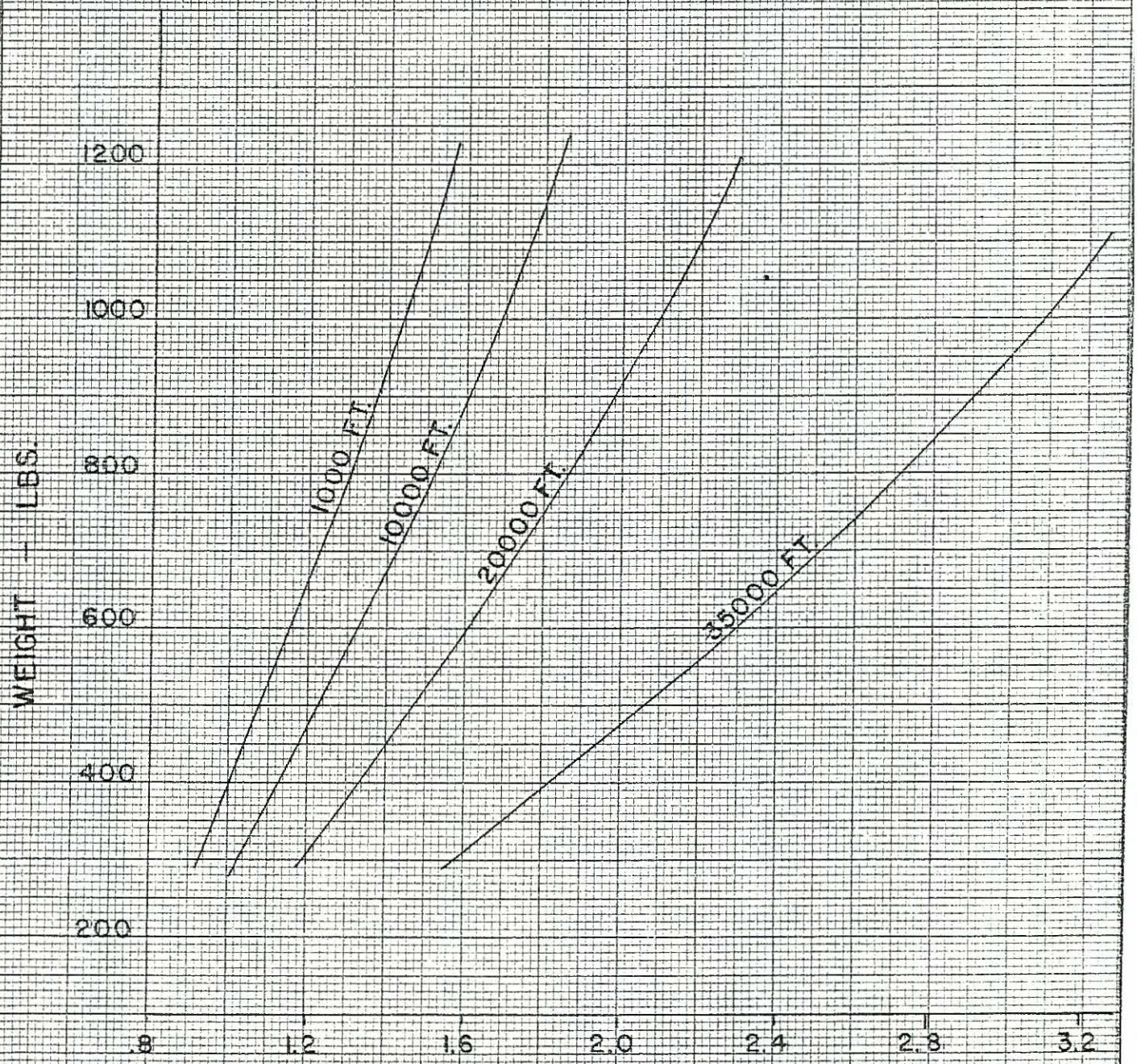

FIG. 1

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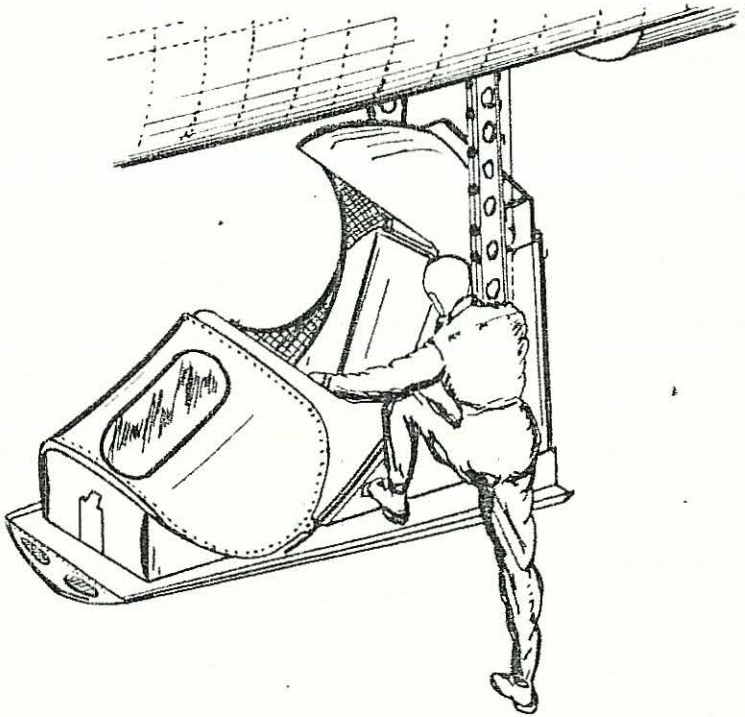

GROUND INGRESS AND EGRESS.

FIG. 3