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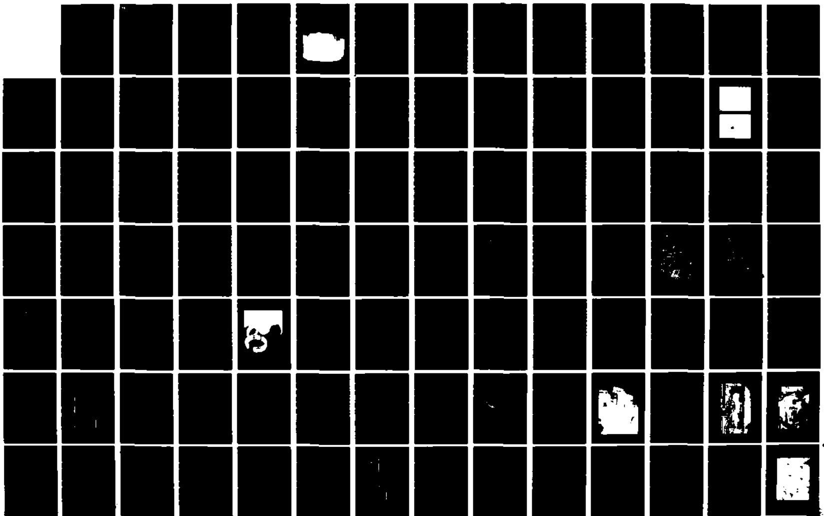

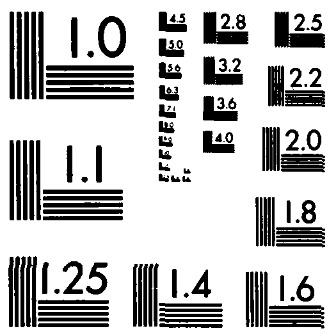
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Report MER0216-FM-8055-5

DESIGN AND DEVELOPMENT OF MILITARY PETROLEUM HOSELINE SYSTEM

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August 1983

Final Report for Period October 1980 - August 1983

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this program has been to develop: a) a self-contained Hoseline Reel Assembly for deploying and picking up 6 inch lightweight, collapsible petroleum hoseline in a tactical situation, and b) a 6 inch diameter lightweight collapsible hoseline. This final report describes the development of the hoseline and the hoseline reel assembly.

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SUMMARY

This report describes the design, fabrication and testing of a prototype Petroleum Hoseline System Hoseline Reel Assembly and 6 inch lightweight, collapsible hose.

The Hoseline Reel Assembly (HRA) is designed to deploy and recover 6 inch diameter lightweight collapsible hoseline at vehicle speeds up to 5 mph in a tactical situation. The HRA is a self-contained, skid-mounted system that can be carried on an M813A2 5 ton truck. Up to four (4) 500 foot lengths of 6 inch hose, stored on two dual reels, can be carried on the HRA. The capability for purging the hose of fuel and evacuating the hose to collapse it prior to recovery is integral with the HRA.

The evolution of the HRA (shown in Figure 1) from initial concept studies through detail design and design modification during testing is discussed. Other areas of discussion include:

a. Deployment/Recovery procedures
b. Deployment/Recovery cycle times
c. Interlocks and safety features
d. Auxiliary support requirements
e. Transportation.

The report concludes with a recommendation for design modifications based on Foster-Miller's observation during DT-1/OT-1 testing.

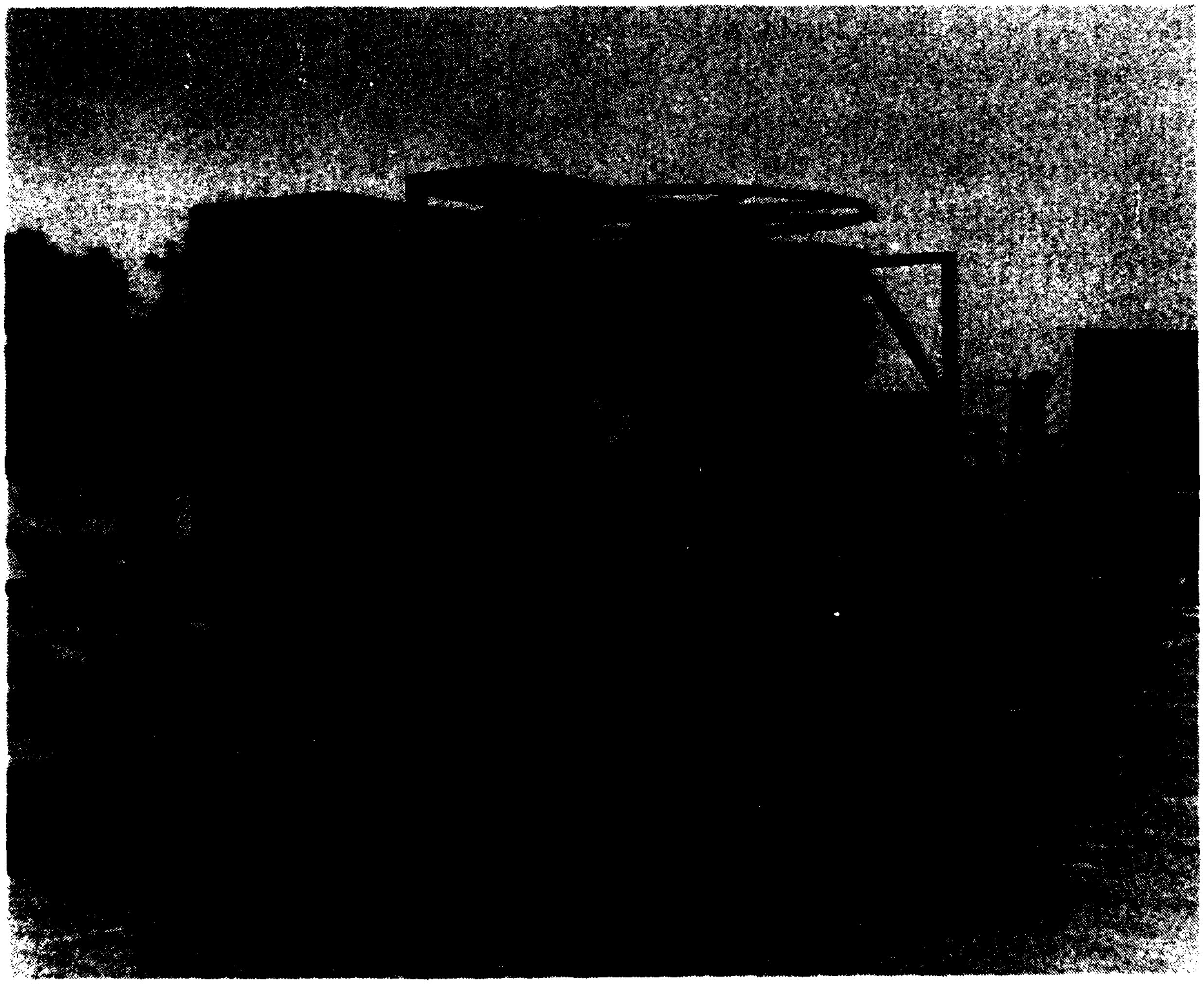

Figure 1. Hoseline reel assembly on M813A2 5 ton truck.

PREFACE

This final report describes the development of the Hoseline Reel Assembly (HRA) and lightweight, collapsible 6 inch hoseline for the Petroleum Hoseline System. The work was performed by Foster-Miller, Inc. of Waltham, MA., under Contract Number DAAK70-80-C-0216 for the Petroleum and Environmental Technology Laboratory of the U. S. Army Mobility Equipment Research and Development Command (MERADCOM) at Fort Belvoir, VA.

The contract has been administrated at MERADCOM by Mr. Herb Rothschild, Contracting Officer and Mr. William Wallentiny, Contract Specialist. Technical direction and supervision has come from Mr. Emil Czul, Contract Officer's Representative.

The program was managed at Foster-Miller by Mr. Frank Graves and Dr. M. Selim Cetiner. Mr. James Finney was the system design engineer.

Major subcontractors to Foster-Miller were Durodyne, Inc. of Tucson, AZ. for the hose development and Assurance Technology Corporation (ATC) of Carlisle, MA., for the Logistics data items and the Technical Manuals.

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FIGURES

FIGURES (Continued)

TABLES

1. INTRODUCTION

The purpose of this program has been to design, fabricate and test a Hoseline Reel Assembly (HRA) and 6 inch diameter lightweight, collapsible hoseline for the Petroleum Hoseline System. The HRA has been designed to deploy and recover the 6 inch lightweight hose at vehicle speeds up to 5 mph under off road conditions. The hose is recovered and stored in a condition ready for immediate redeployment. An on-board air compressor and air ejector provide the capability to purge the hose of fuel and collapse it prior to recovery, without ancillary support equipment.

The Petroleum Hoseline System will provide the faster reaction times and greater flow capabilities required for the Army's fuel needs of the 1980s. The Petroleum Hoseline System will provide a throughput capacity of at least twice the capacity of the existing 4-in. Hoseline Outfit FSN 3835-392-5157. Furthermore, the hose will be stored on reels in the Petroleum Hoseline System, eliminating the 180° folds required for flaking. Hence, the hose storage life should be greatly improved.

The flaking box system currently used with 4 inch hose involves a very time consuming, labor intensive recover/repacking operation. With the powered reel on the HRA, the recover operation is dramatically improved.

2. ENGINEERING DEVELOPMENT GOALS FOR THE PETROLEUM HOSELINE SYSTEM

The major characteristics of the Petroleum Hoseline System are listed below. Not all of the listed items apply to the work conducted by Foster-Miller, Inc., or its subcontractors. For instance, any reference to pumping capacity is applicable only to the hose, as the pump, its construction, capacity, and maintenance characteristics, are not a deliverable of the contract.

The Petroleum Hoseline System is designed to meet following requirements:

a. Fuel flow capacity requirements will be based on a 6-in. hose diameter with a through put capacity of 600 to 800 gal/min.

b. Each hose section will be of the maximum continuous length consistent with the operational characteristics of the system and with available hose fabrication technology. The length of a basic system will be 8,000 to 10,000 ft. However, systems will be capable of interconnection and partial deployment. Two or more systems may be interconnected when the need exceeds the capability of one system.

c. The weight and bulk of the hose will be kept to a minimum while maintaining sufficient strength required for compatibility with standard military pumping equipment and transporting capability.

d. The equipment will be packaged to permit rapid deployment of hose sections when a complete assembly is not required.

e. The Petroleum Hoseline System will consist of: a pump-engine assembly with manifold; the maximum length of hoseline (8,000 to 10,000 ft) consistent with the desired rate of flow (600 to 800 gal/min) and maximum safe operating pressure; equipment for hoseline deployment, handling, recovery and storage and required ancillary items.

f. The pump assembly will have the following characteristics:

1. Must be capable of being mounted, transported, and operated on a two- or four-wheel standard military trailer. Trailer will be equipped with handbrake and jackstands.

2. Will be required to operate continually for 17 hr at minimum capability without external support except fuel. The fuel tank capacity shall be sufficient for not less than 8 hr of continuous operation at the rated load. The fuel cell will have the capability of being refueled by standard military fuel dispensing equipment.

3. Will be capable of delivering a minimum of 600 gal.min at a minimum of 150 $lb/in.^2$ when employed with the hoseline.

4. Will be equipped with an automatic pressure-sensing pump-protection device compatible with system requirements.

5. Will be driven by a diesel engine.

g. Pressure/flow regulators will be provided if necessary for the pumping equipment.

h. A powered reel-type mechanism or other mechanical means will be developed for hoseline storage, deployment, purging and evacuation of the line fill and hoseline retrieval.

i. The system will permit deployment and retrieval at a rate of 1 to 1.5 mi/hr.

j. The Petroleum Hoseline System will be capable of being employed, operated, retrieved, stored and transported in climatic categories 1 through 6 as defined in AR 70-38.

k. The system will be designed to assure operational effectiveness, conformance to system safety criteria per Military Standard 882A, Military Standard 1472, AR 385-12, and freedom from health hazards, to include personnel/materiel interface aspects of system effectiveness defined in AR 602-1.

l. The Petroleum Hoseline System will be transportable by ocean cargo ship, C130, C141, and C5A cargo aircraft, railcar, utility helicopters and cargo trucks.

m. All components must be sufficiently rugged that, when properly prepared for shipment, must conform to the transportability criteria for highway, rail, water, and air transport as specified in AR 70-44 and AR 70-47.

n. The system will be packaged to permit shipment within standard American National Standard Institute (ANSI) and International Standards Organization (ISO) intermodal cargo containers.

o. The system must be capable of being installed, operated and recovered with the personnel (5th percentile female and 95th percentile male) and skills found in petroleum supply companies, petroleum pipeline and terminal operating companies and supply and service companies.

p. System will be designed to use standard tools where possible. Special tools, if required, will be provided with the system.

q. A hoseline shelf-life of 10 years will be established as a development goal.

r. System must be capable of being camouflaged using natural cover or concealment. Pump stations can be camouflaged with nets and protected by utilizing sandbags for revetment.

s. The system will be capable of handling logistics fuels currently in use by the U.S. Army, the sister services, ABCA nations, and NATO.

t. NBC Vulnerability - The Petroleum Hoseline System will be capable of operation in a toxic environment by personnel in full protective ensemble and mask. The system will be capable of being decontaminated of residual BC agents and radioactive particles. Painted with chemical resistant paint in accordance with Mil. Spec. MIL-C-46168A to facilitate decontamination.

u. Reliability, Availability, and Maintainability (RAM) requirements will be jointly determined by the materiel and combat developers throughout the development process and as the system is satisfactorily tested and agreed upon that the system satisfies the stated need. Minimum acceptable value (MAV) for the pump assembly is 200 hr mean time between failures (MTBF).

3. CONCEPT DEVELOPMENT AND EVALUATION

The first major task of the Hoseline Reel Assembly (HRA) design process was to conduct the initial systems analysis necessary to identify and select the best technical approach. Three major studies were conducted to arrive at the best answer to the problem. One was a hose reel density study. The second was an operational procedure analysis, while a third study dealt with the many tradeoffs necessary among such broad areas as: human factors engineering; transportability; reliability, availability and maintainability; productivity; and energy consumption. Each study contributed key elements to the engineering specifications that defined the HRA.

3.1 Hose Reel Density Study

There were three parallel efforts in this study. The first was a volume calculation study to find out how much hose could be stored on each of a number of reel configurations. The second was an experimental study of hose supplied by the hose manufacturer, Durodyne, Inc., to determine its performance on a reel in terms of packing density, hose dogbone size under vacuum, etc. The third was a design study to define the minimum reel hub size that would contain a hose end fitting without subjecting the hose to undue stress in the form of a sharp reverse bend.

3.1.1 Reel Volume Calculation Study - Four different reel types were investigated. They are shown in Figures 2 through 5.

Reel dimensions and configurations were developed for reels holding 500 ft of hose. In all cases, the following assumptions applied:

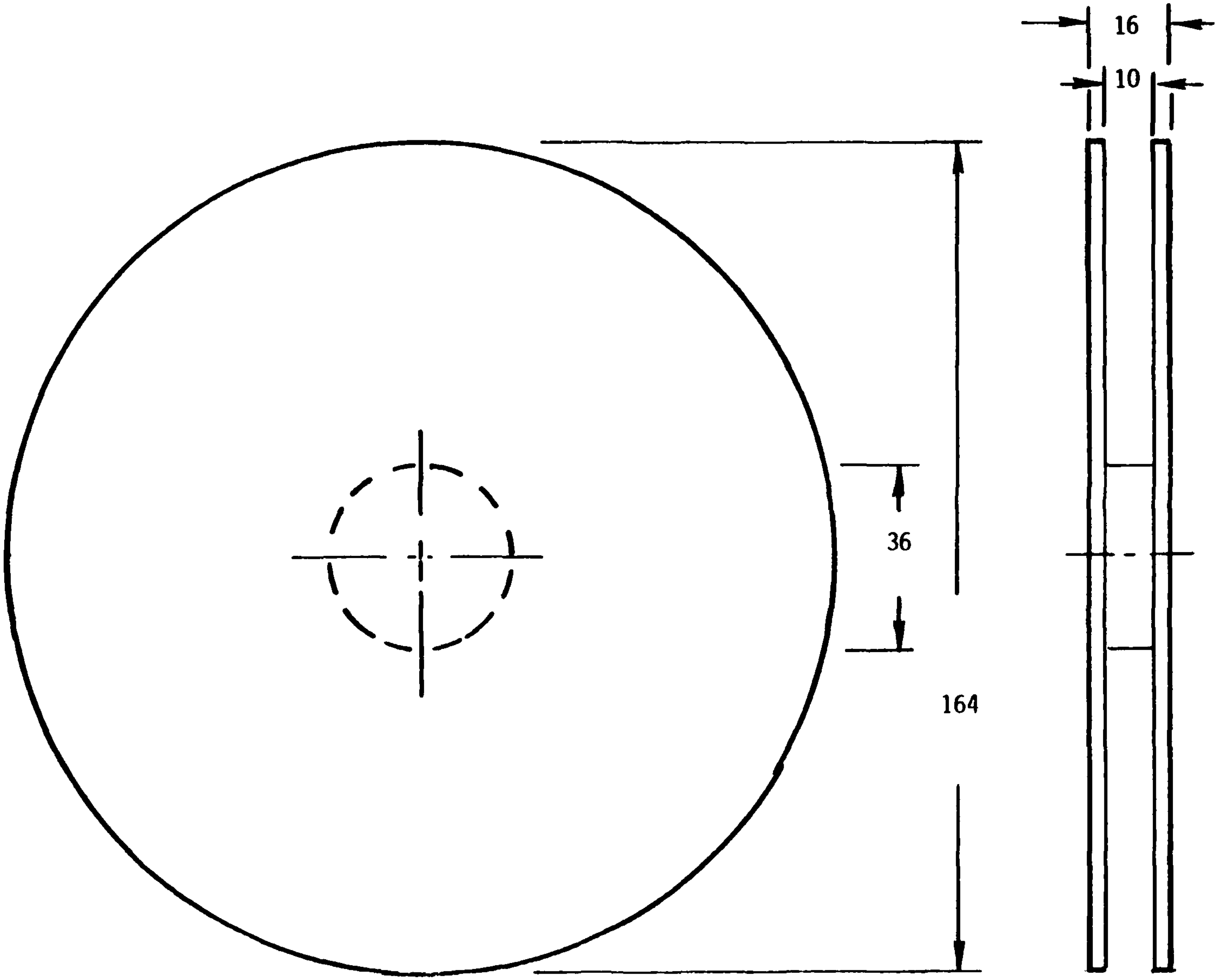


Figure 2. Single row oversize reel.

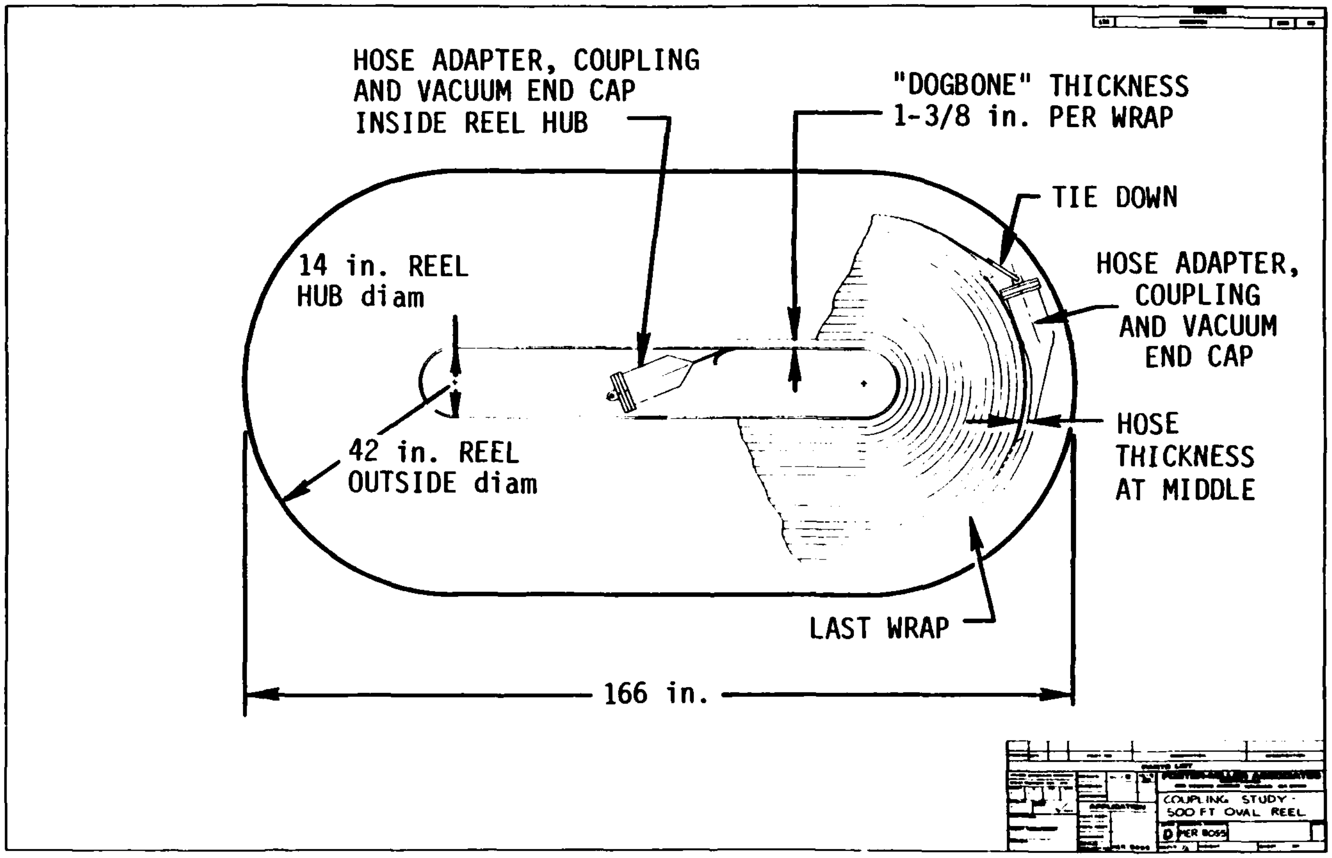


Figure 3. 500 ft oval reel.

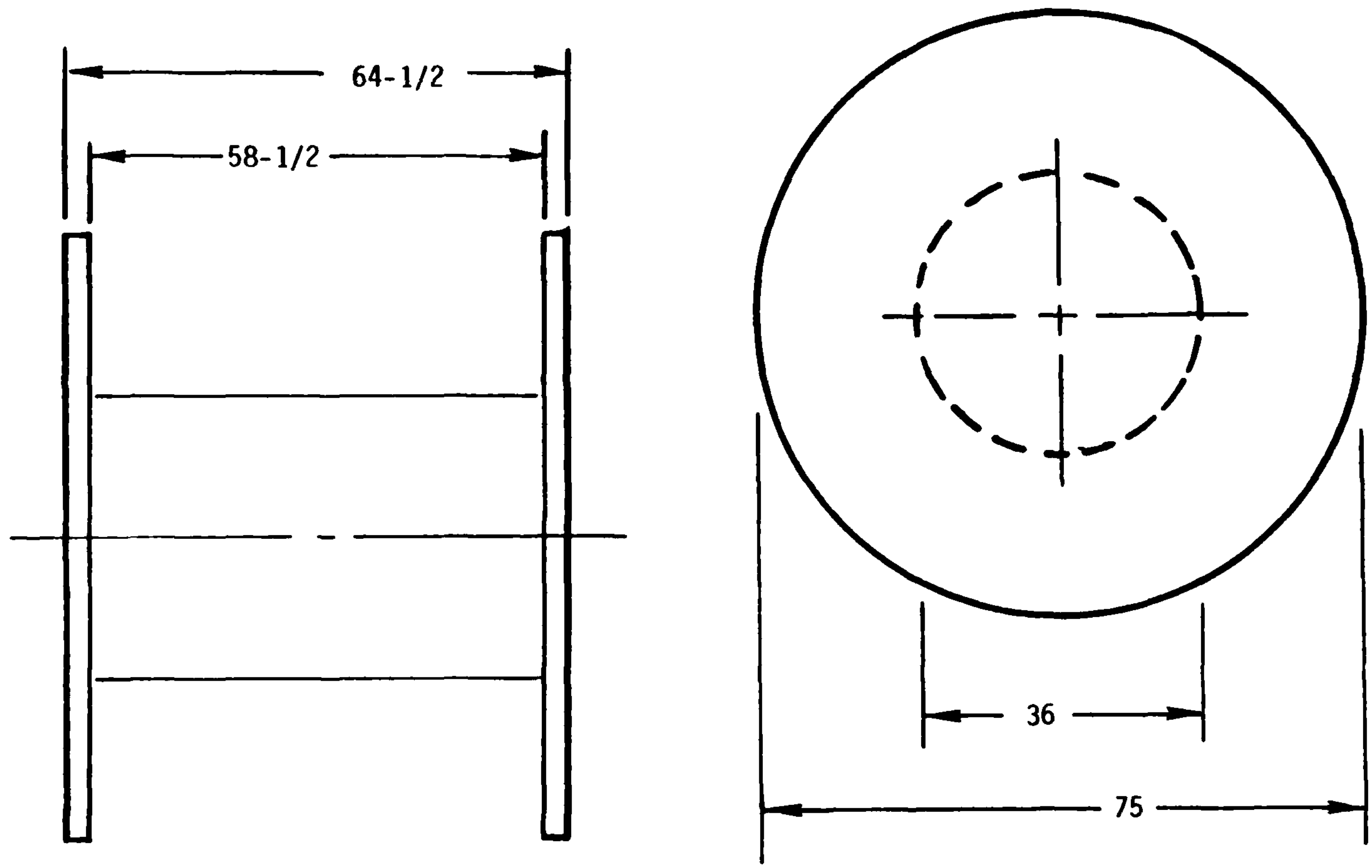


Figure 4. Spiral wound multiwrap reel.

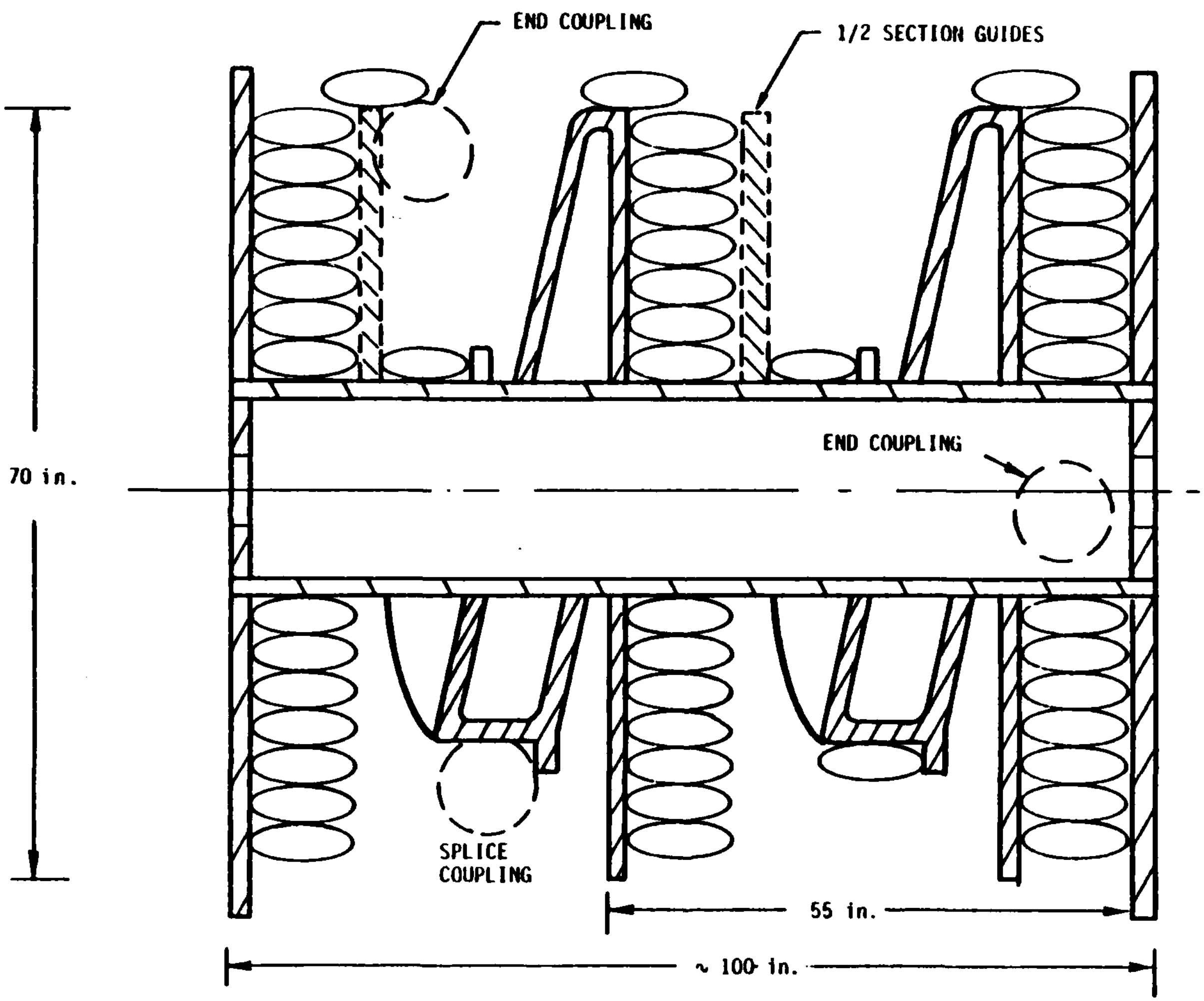


Figure 5. Two section reel design.

a. The hose dogbone thickness was assumed to be 1.375 in. when collapsed. This was based on preliminary data supplied by Durodyne based on a hose weighing 3.25 lb/ft. The delivered hose had a dogbone thickness of about 0.85 in. and weighed 2.75 lb/ft.

b. The hose was assumed to lay on the reel as a flat belt with the thickness of the dogbone.

c. Room was included for a Victualic style coupling at each end of the hose.

d. No coupling or splice was included in the middle of a length of hose.

e. All reels were required to fit into an ISO standard shipping container.

The results of this study are shown in Table 1. Note the marked difference in shipping densities obtained for the various reels (feet/hose/container). All of the results of Table 1 take account of the conditions imposed by the reel hub study. While the data in Table 1 is based on dogbone thickness of 1.375 in. rather than the actual thickness of .85, the results are valid for purposes of comparison.

3.1.2 Reel Hub Study - The packing density achieved with each of the four reel types being considered was greatly influenced by the inner hub size chosen. The hub size had to be large enough to contain the metal hose end with its plug and clamp. The hub design used early in the concept development is shown in Figure 6. The important item here is the minimum hose radius allowed to exist where the first wrap of hose exits the hub. Too sharp a bend is equivalent to the problem of flaking a hose the sharp bend is a fatigue point in the hose which eventually begins to leak. The hub of Figure 6 was used in the evaluation described in subsection 3.1.1.

TABLE 1. REEL SUMMARY

	Round single row	Round multirow	Round helical wound	Oval single row
Packing vol/500 ft	116 ft^3	154 ft^3	115 ft^3	64 ft^3
Reel vol/500 ft	196 ft^3	223 ft^3	165 ft^3	118 ft^3
Hose/container ft	0	1000 ft	1500 ft^3	2500 ft^3
Mass moment of inertia $lb\text{-}ft/sec^2$	530	-	202	622

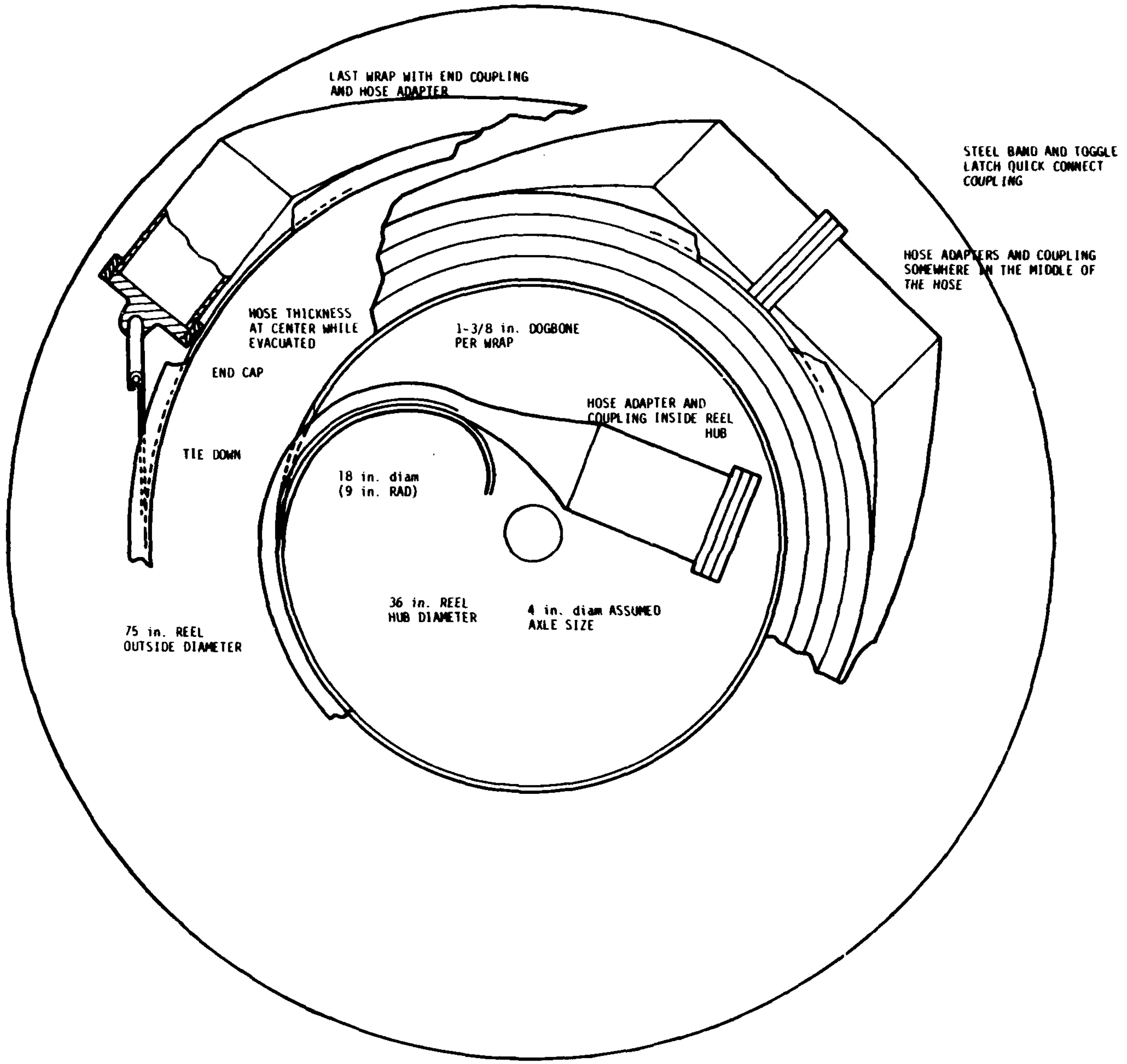


Figure 6. Coupling placement and storage study.

Later, as a result of the experimental program, a modified reel hub was designed for use in the single row reel. It is described later in this report, in subsection 4.2.

3.1.3 Experimental Hose Analysis - Two short pieces of hose (50 to 100 ft) were provided by Durodyne during Phase I of their subcontract. Each hose was subjected to laboratory evaluation to determine its performance characteristics relative to packing and deployment. The first hose evaluated weighed 3.25 lb/ft and displayed the characteristics shown in Figure 7. This 3.25-lb/ft hose could be evacuated to maintain a dogbone thickness of 1.2 to 1.3 in. The hose wrapped on a 40-in. diam reel with 17-in. Hg vacuum inside which was producing a thickness of 1.06 to 1.22 in. per layer. Apparently, the curvature and tensile force necessary to wrap it by hand were enough to flatten the dogbone somewhat.

An important observation of this test was the importance of using a collapsed hose for any automatic feed mechanism. If an open-ended or uncollapsed hose is bent in a shape resembling the form it would take alongside the truck, it tends to buckle at random points, and rises from the ground as a series of short segments. This behavior is shown in Figure 8. Behavior of this type would be undesirable with reeling systems which respond to the shape of the hose as their key to maintaining the proper reeling speed. Jerky motion could result from the random straight segments.

The hose's performance is much more predictable and uniform when fully collapsed. As Figure 9 shows, the evacuated hose performs like a flat belt, and displays a regular, smooth curve when it rises from the ground. The smoother profile is advantageous in efforts to automate the Deployment/Recovery operation.

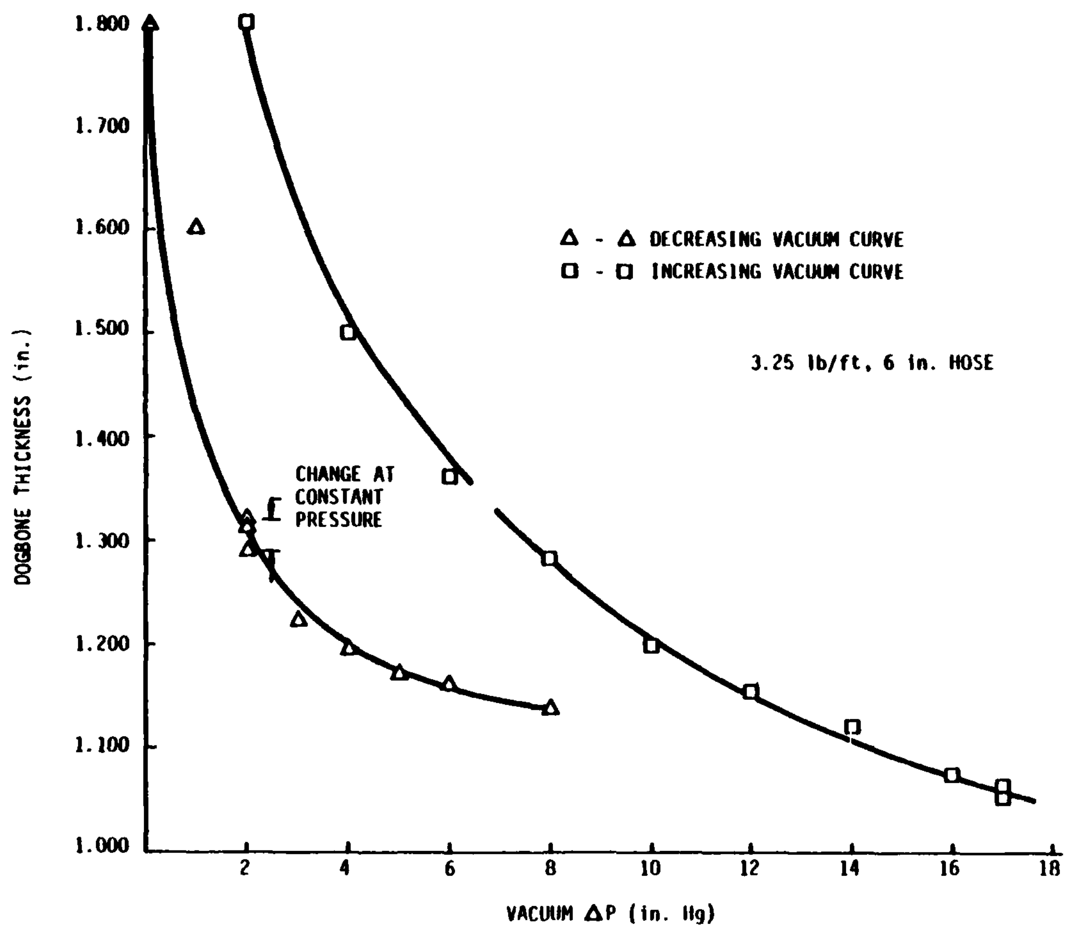


Figure 7. Hose dogbone thickness change under vacuum.

Figure 8. Hose curve without vacuum.

Figure 9. Hose curve with vacuum.

A second hose weighing 2.75 lb/ft was evaluated later in Phase I. It represents the reasonable limit in weight reduction for this size and type of hose construction. With this hose, dogbone heights on the order of 0.82 to 0.85 in. were recorded at a vacuum level of 25 in. Hg. The vacuum was obtained with a Penberthy GH-1/2 ejector similar to the GL-1 being provided with the Petroleum Hoseline system. The vacuum level was also obtained and held unchanged for 40 min using Victualic-type seal gaskets. The hose wrapped on a 30-in. diam reel produced layer thicknesses averaging 0.85-in. thick. The dimensions of this hose proved to be the measurements which prevailed in the final hose delivered with the Petroleum Hoseline System.

3.2 Operational Procedure Analysis

An operational procedure analysis was done to isolate and quantify critical parameters of the deployment/recovery process and establish realistic goals for the design process.

A basic time study showed that the truck is not a major factor in the overall deployment rate. Taking into account the need to operate off the road, a fundamental constraint of 7 mi/hr was initially put on the truck's speed. This represents top speed in first gear with the manual transmission of the M813A truck in high range on the transfer case. Several benefits are obtained from this. The principal one is that gear changes are not required during laying a hose. The transmission can be put in first gear, high or low range, and left there depending on the terrain. With this simplification, acceleration and deceleration rates are more predictable. The deployment can also utilize a less skillful operator with this simplification.

An important aspect of selecting the truck speed is that the rate at which the hose must be discharged or recovered can then be determined. This has importance in defining the hose reel drive. In conjunction with such variables as reel diameter, hose tension, acceleration profiles, and reel inertia, truck speed determines the reeling power required.

During the operational procedure analysis, the truck acceleration/deceleration profile was defined to be a speed of 7 mi/hr obtained at a distance of 50 ft from a standing start. Constant acceleration was assumed.

Once the truck speed, and thus the peak deployment/recovery rate, had been defined, an overall deployment rate could be developed using time simulation techniques. In the course of developing the simulation data, the subtleties of laying a hose were further exposed. As shown in Tables 2 and 3, it became clear that the dominant factors that governed the deploy time were the time to change reels and the time to remove and install couplings and end plugs. Obviously if more hose can be carried on-board, the number of reel changes can be reduced. In this case the coupling/uncoupling time is the single most important factor affecting deploy rate.

Referring to Tables 2 and 4, it is seen that the single most important factor governing the recovery rate is the time required for fuel evacuation. The relative signicance of the reel change time, hose threading and coupling times are seen to be dependent on the reel configuration, i.e., the amount of hose carried on-board the HRA.

Another item of signficance, closely associated with loading, was the amount of time required to thread a hose through the HRA index rolls and pinch rolls.

The various elements of the deployment/recovery cycle that were identified during the operational procedure analysis are shown in Table 2. The items of equipment found to give the best simulated

TABLE 2. CYCLE TIMES (ITEMIZED)

CYCLE TIMES (ITEMIZED)

1. DEPLOY CYCLE TIMES

1.1 Reel Change	Time (sec)
Position trucks	30
Move lift over reel (empty)	10
Hook to lift	20
Lift and swing over	30
Unhook reel	20
Move lift to full reel	10
Hook to full reel	20
Lift and swing over	30
Position and place full reel	20
Unhook full reel	20
Fold reel out of the way	10
Total reel change time	230

1.2 Deploy Hose	300-ft Hose	500-ft Hose
Unhook outer coupling	10	10
Thread the hose	20	20
Clamp hose end and remove plug	45	45
Couple the hoses	60	60
Remove clamp	10	10
Deploy the hose	35	50
Unthread the hose	20	20
Total deploy hose	200	215

2. RECOVER CYCLE TIMES

2.1 Evacuate Fuel (one hose at a time)	300-ft Hose	500-ft Hose
Clamp end of hose	10	10
Install rubber ball and end plug	60	60
Hook up compressor, unclamp hose	15	15
Evacuate 1 length, 70 ft^3/min	103	171
Evacuate 1 length (400 ft^3/min)	18	30
Clamp the ball	15	15
Unhook compressor	10	10
Bleed the air	18	30
Uncouple the hoses	30	30
Plug end of hose	60	60
Total evacuate fuel, 70 ft^3/min	321	401
Total evacuate fuel, (400 ft^3/min)	236	260

2.2 Evacuate Fuel (10,000 ft line)	10,000-ft
Clamp end of hose	15
Install ball ejector	60
Hook up compressor	10
Evacuate the line, 70 ft^3/min	3428
Evacuate the line, 400 ft^3/min	600
Bleed the air	400
Unhook compressor	10
Unhook ball ejector and receiver	45
Total evacuate fuel, 70 ft^3/min	3968
Total evacuate fuel, 400 ft^3/min	1140

2.3 Collapse the Hose (70 ft^3/min)	300-ft hose	500-ft hose
Hook up ejector	10	10
Hook up compressor	10	10
Pull vacuum	103	171
Unhook compressor and ejector	20	20
Total vacuum	143	211

2.4 Recover the Hose	300-ft hose	500-ft hose
Thread hose end	30	30
Secure hose end	30	30
Pick up hose	35	50
Unthread hose	20	20
Secure hose end	30	30
Total Recover	145	160

TABLE 3. DEPLOY CYCLE TIMES FOR 10,000 FT LONG HOSELINE

	PERCENT OF TOTAL TIME		
	SINGLE WRAP (500 FT)	4 WRAPS (300 FT)	4 WRAPS (500 FT) EACH
1. CHANGE REELS	52	22	21
2. THREAD AND UNTHREAD HOSE	11	19	18
3. COUPLINGS AND END PLUGS	26	45	42
4. DEPLOY HOSE (AT 7 MILES PER HOUR, MAXIMUM)	11	13	18
HOURS TO DEPLOY 10,000 FT	2.47	2.38	1.51

TABLE 4. RECOVER CYCLE TIMES FOR 10,000 FT LONG HOSELINE

	PERCENT OF TOTAL TIME		
	SINGLE WRAP (500 FT)	4 WRAPS (300 FT)	4 WRAPS (500 FT)
A. EVACUATE TOTAL LINE FIRST			
1. FUEL EVACUATION, 70 CFM	32	33	64
(400 CFM)	9	9	12
2. CHANGE REELS	36	16	12
3. THREAD AND UNTHREAD HOSE	14	25	20
4. UNCOUPLING THE HOSE	9	16	13
5. RECOVER THE HOSE	8	9	11
HOURS TO RECOVER 10,000 FT, 70 CFM	3.49	3.35	2.53
(400 CFM)	(2.71)	(2.56)	(1.75)
B. HOURS TO RECOVER 10,000 FT ASSUMING PARALLEL OPERATION WITH 400 CFM AND 70 CFM (HOURS)	3.34	3.20	2.38
C. HOURS TO RECOVER 10,000 FT ASSUMING EVACUATION OF ONE LENGTH AT A TIME WITH 70 CFM ONLY (HOURS)	5.45	5.98	4.50

rates are shown in Figures 10 and 11. The results of the simulation for a single 500-ft hose reel, and the final design consisting of two dual wrap reels containing a total of four 500-ft hoses are shown in Tables 3 and 4. (The evolution of the design will be covered in more detail later.) The calculated deployment time for the design shown in Figure 1 is 1.5 hr for 10,000 ft of hose and a vehicle speed of 7 mph. The recovery time is 4.5 hr for 10,000 ft using only the air compressor on-board the HRA skid itself to purge the hose of fuel one length at a time. With a supplemental 400 ft^3/ min air compressor used for purging, this time could be reduced to 2.4 hr. The difference between deploy and recover is largely the time necessary to clear the hose of fuel and collapse it.

The time to evacuate fuel from the hose and consequently the recovery rates is influenced by the length of hose to be evacuated in a single step. If several 500 ft lengths remain coupled together and are evacuated in a single step, the evacuation time can be reduced.

3.3 Fundamental Arrangement Study

The third concept development study of the initial systems analysis phase was concerned with the basic skid arrangement and its impact on the overall project. The seemingly simple task of selecting a reel and positioning it on the base had a profound effect on all other aspects of the machine's production and use. Nine distinct skid system candidate concepts were generated and evaluated for their merit in a variety of categories. All were restricted to discharge their hose off the right rear corner of the skid.

The nine candidate skids are shown in Figures 12, 13 and 14. Figure 12 shows three variations of a single wrap reel on a skid. Figure 13 shows three possible configurations for a skid with a reel carrying 500 ft of hose in a spiral-wound multiwrap configuration similar to that shown in Figure 4. Figure 14 shows a group of skids with a 1000-ft spiral-wound multiwrap reel.

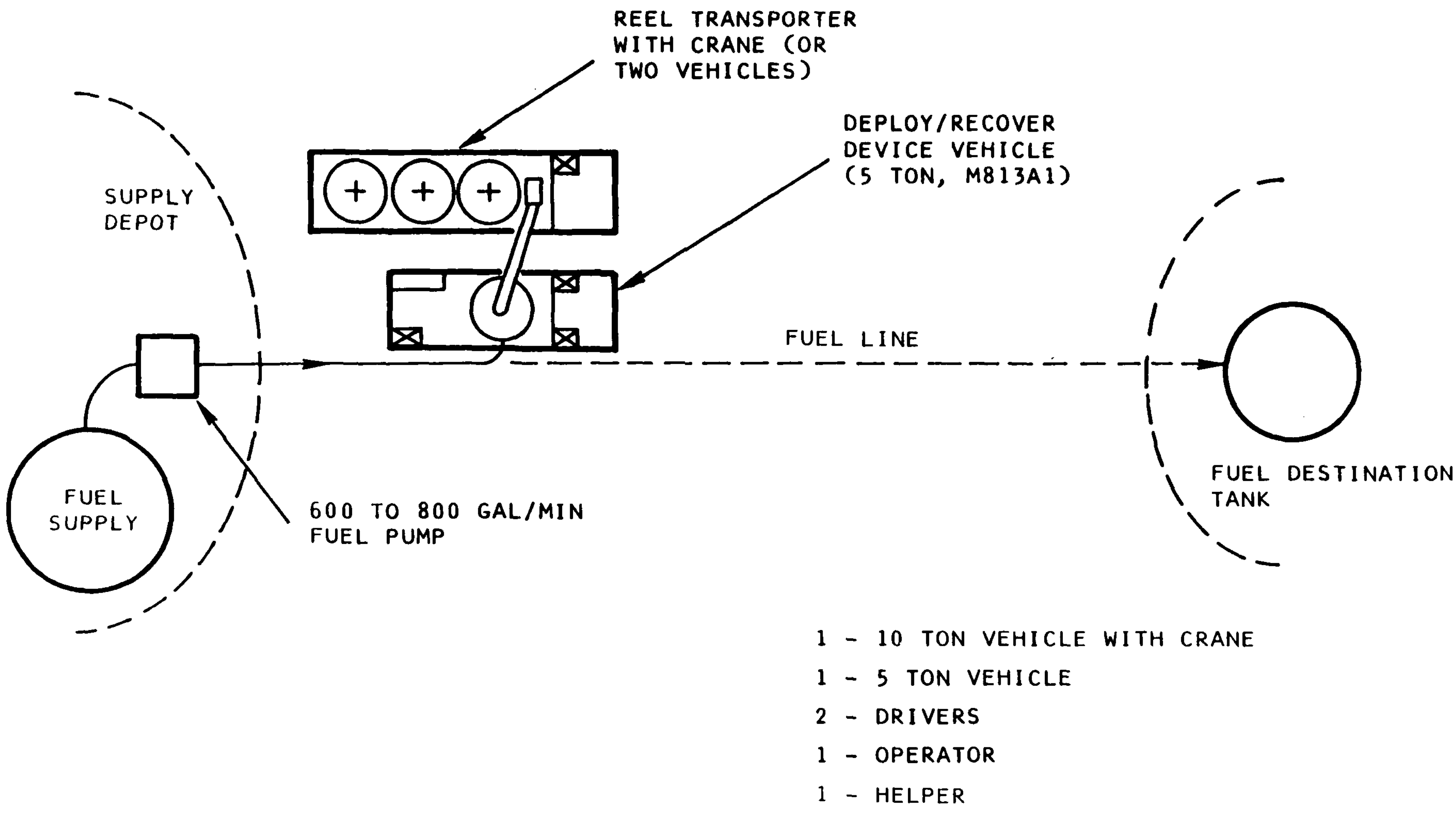


Figure 10. Deploy cycle equipment and personnel (10,000 ft hoseline).

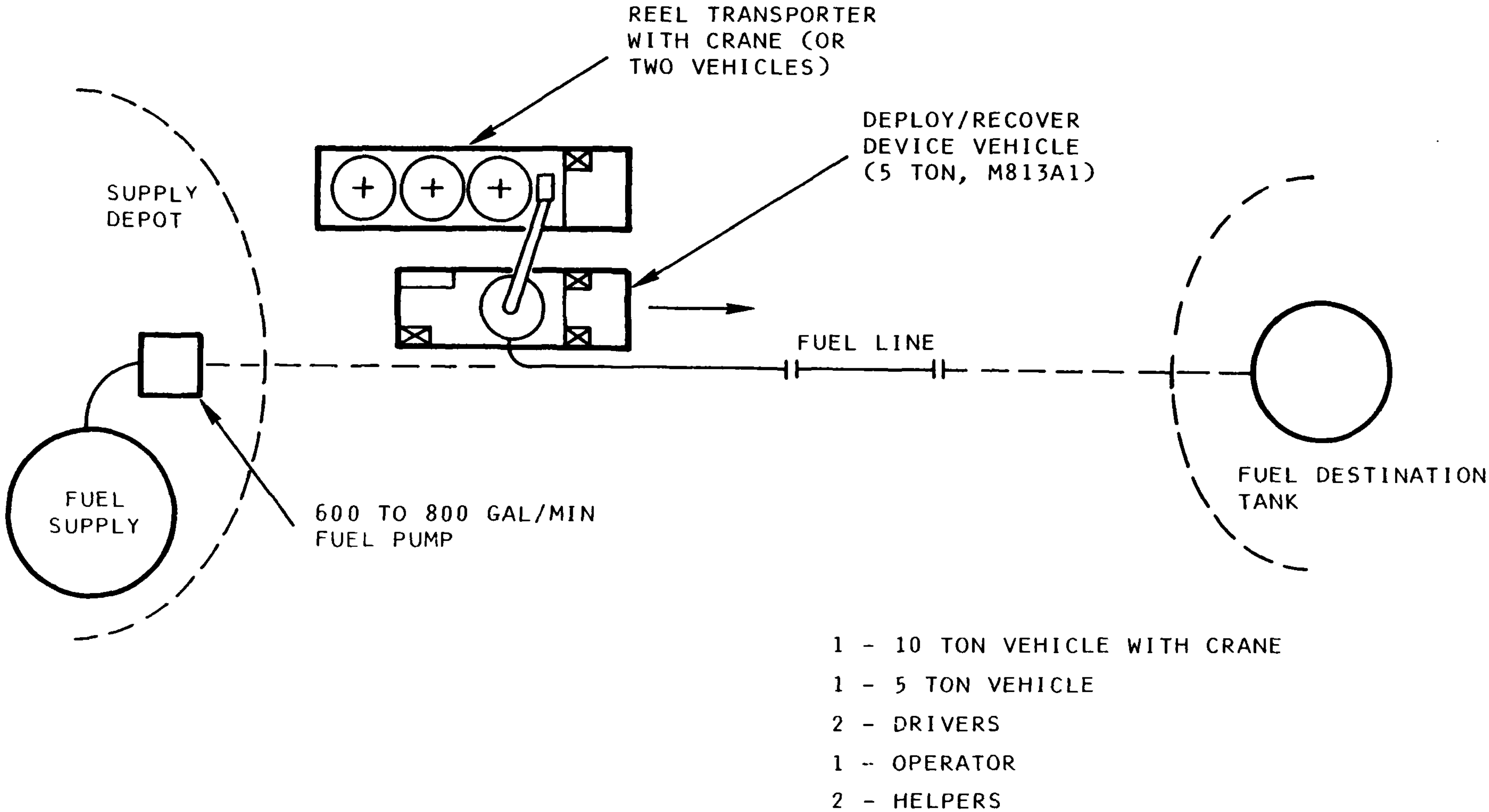


Figure 11. Recover cycle equipment and personnel (10,000 ft hoseline).

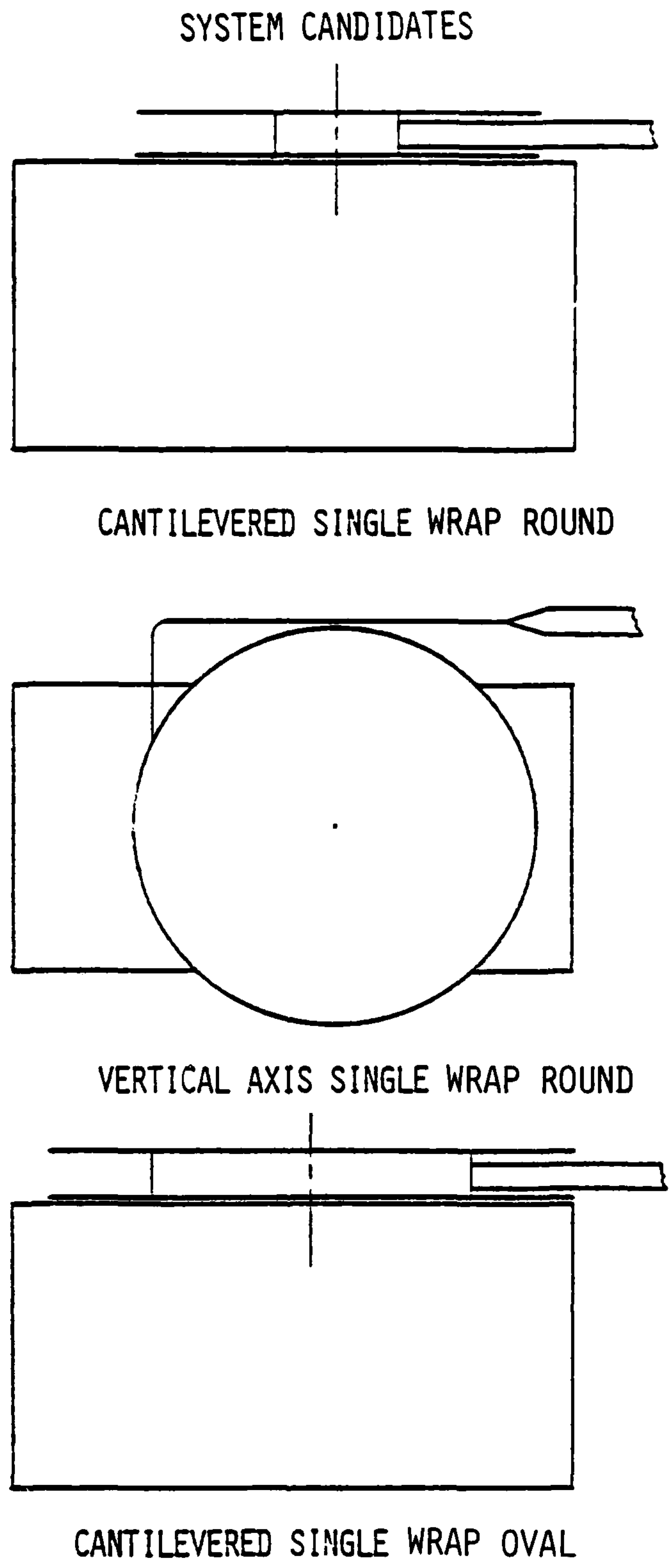
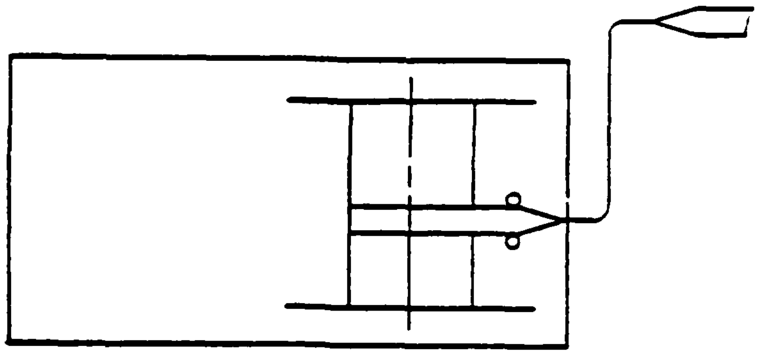
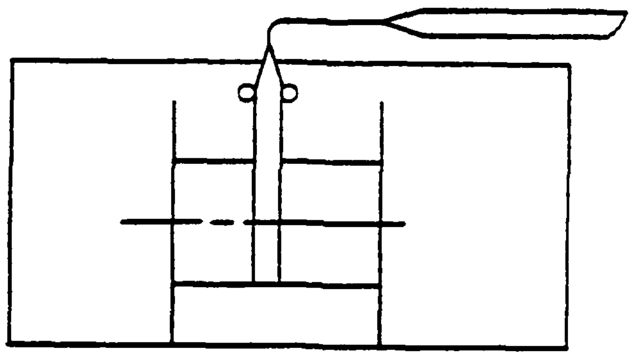


Figure 12. System candidates.

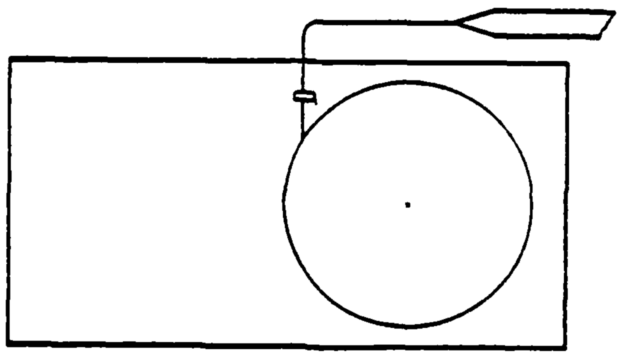
SYSTEM CANDIDATES



500 FT TRANSVERSE AXIS SPIRAL WOUND



500 FT LONGITUDINAL AXIS SPIRAL WOUND



500 FT VERTICAL AXIS SPIRAL WOUND

Figure 13. System candidates.

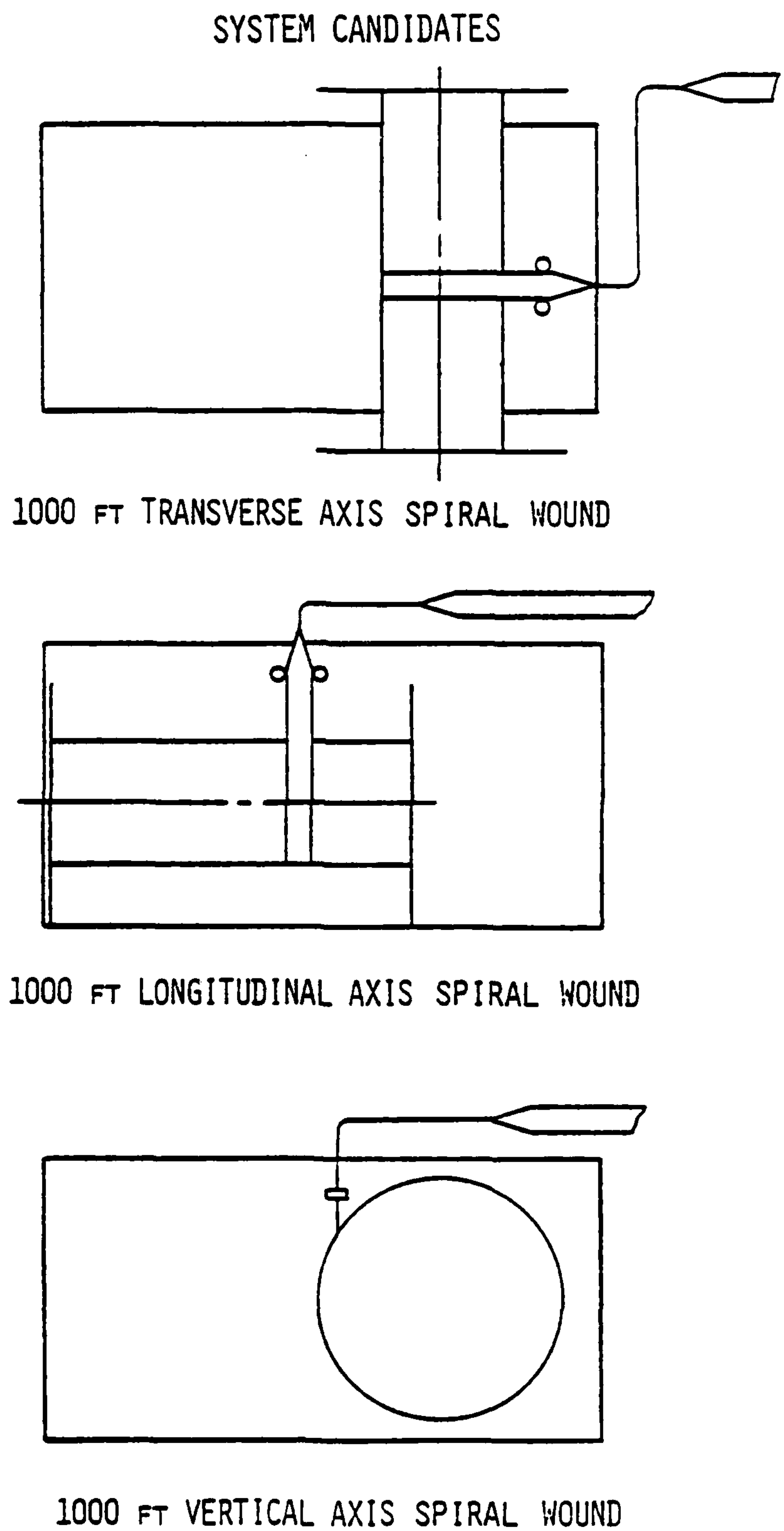


Figure 14. System candidates.

It is immediately obvious that the space utilization differs in the nine concepts. Some leave virtually the whole skid available to mount auxiliary subsystems such as the power plant and operator's station; others leave little room for these items. A great number of similar observations can be made about the nine configurations. A way was needed to consolidate these observations and rate the skid systems for their overall accommodation to the problem of laying a hose in a military environment. A matrix evaluation technique was selected to measure this overall suitability.

A group of 20 general categories of performance were established through reference to the contract and through the combined experience of the design staff. These categories were weighted as to their relative importance to a final design by four experienced engineers on the basis of 100 being most important and 0 being least important.

The composite chart of the chosen categories and their resulting weights is shown in Table 5.

Each of the nine candidate skids was then scored in each category by each engineer using the scale of Figure 15. For each skid, each engineer created a total score by multiplying each category score by its weight and taking the sum of the weighted scores. The relative ranking of the nine evaluated skid arrangements is shown in Table 6. Several trends are detectable here. Side-mounted reels were judged best. Single-width reels were judged best. The 500-ft version is of the spiral-wound multiwrap reels were consistently better than the 1000-ft versions.

Concept drawings of a number of the nine skids were made showing the machinery mounted on a 5-ton M813A2 military truck. These are shown in Figures 16 through 22. From this group of drawings, the decision to present Figure 17, the oval reel, and Figure 19, the 500-ft spiral-wound, multiwrap configuration,

TABLE 5. MATRIX EVALUATION CATEGORIES AND WEIGHTS

CATEGORY	WEIGHT	CATEGORY	WEIGHT
RELIABILITY	77	SETUP TIME	57
AVAILABILITY	68	OPERATOR INVOLVEMENT	42
MAINTAINABILITY	77	OPERATIONAL EASE	65
DESIGN COST	22	OPERATIONAL FLEXIBILITY	48
ACQUISITION COST	30	SAFETY	58
LIFE-CYCLE COST	37	NOISE	48
SCHEDULE	67	HUMAN FACTORS	47
CYCLE TIME	83	WEIGHT	50
EFFECTIVE USE OF VOLUME	50	STATE-OF-THE-ART	43
TRANSPORTABILITY	58	POWER CONSUMPTION	17

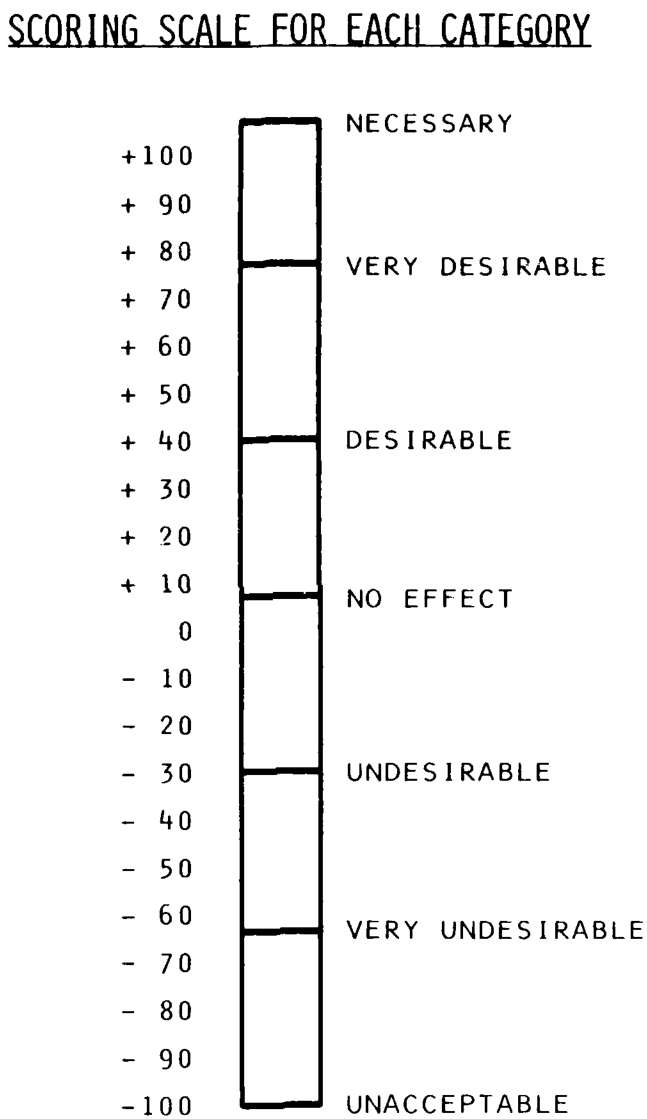


Figure 15. Scoring scale for each category.

TABLE 6. MATRIX EVALUATION RESULTS

1. SIDE MOUNT SINGLE-WIDTH ROUND REEL	500 FT
2. SIDE MOUNT SINGLE-WIDTH OVAL REEL	500 FT
3. VERTICAL AXIS SINGLE-WIDTH ROUND REEL	500 FT
4. MULTIWIDTH LONGITUDINAL REEL	500 FT
5. MULTIWIDTH LONGITUDINAL REEL	1000 FT
6. MULTIWIDTH VERTICAL AXIS REEL	500 FT
7. MULTIWIDTH VERTICAL AXIS REEL	1000 FT
8. MULTIWIDTH ACROSS BED REEL	500 FT
9. MULTIWIDTH ACROSS BED REEL	1000 FT

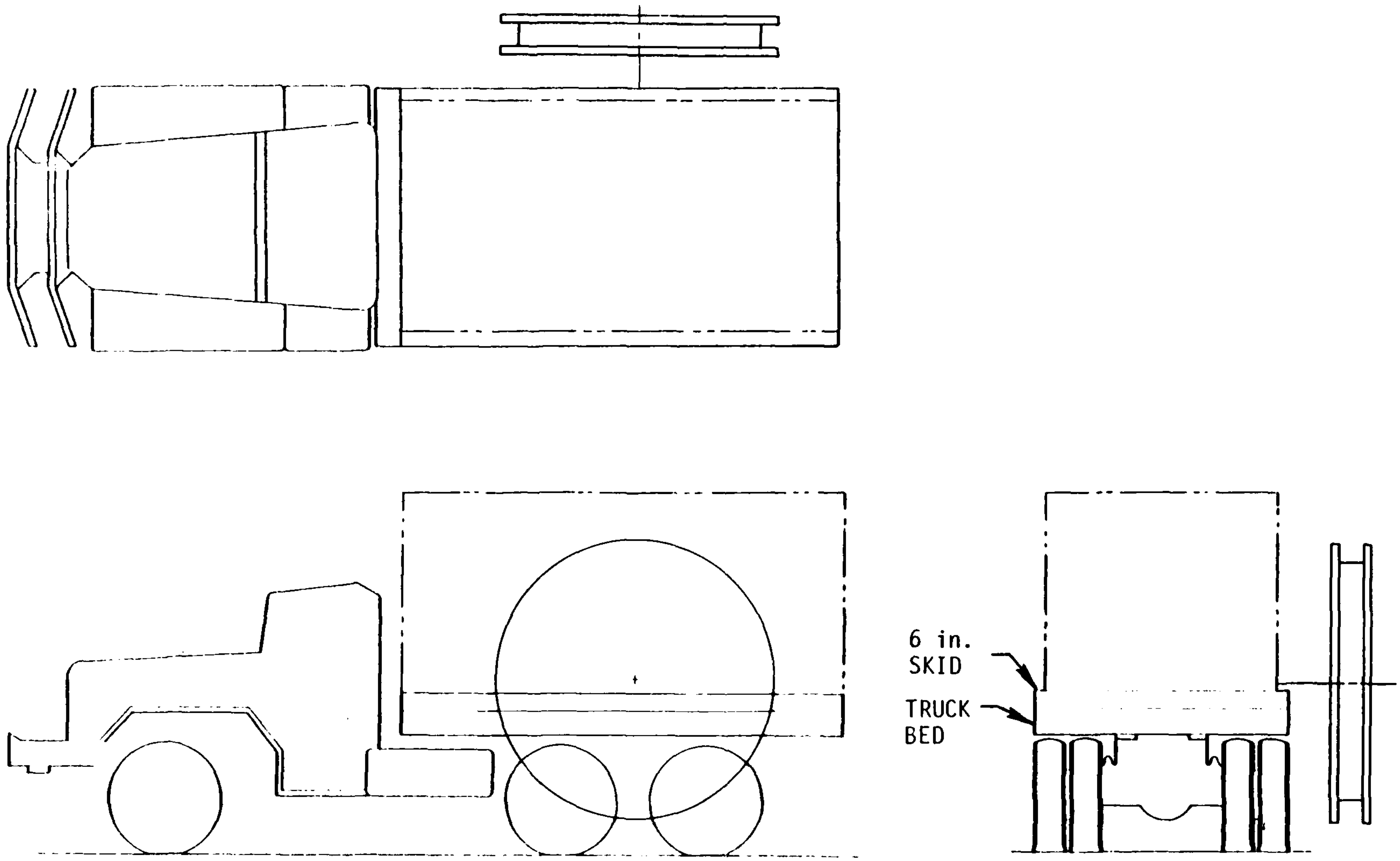


Figure 16. 500 ft single-wrap reel horizontal axis.

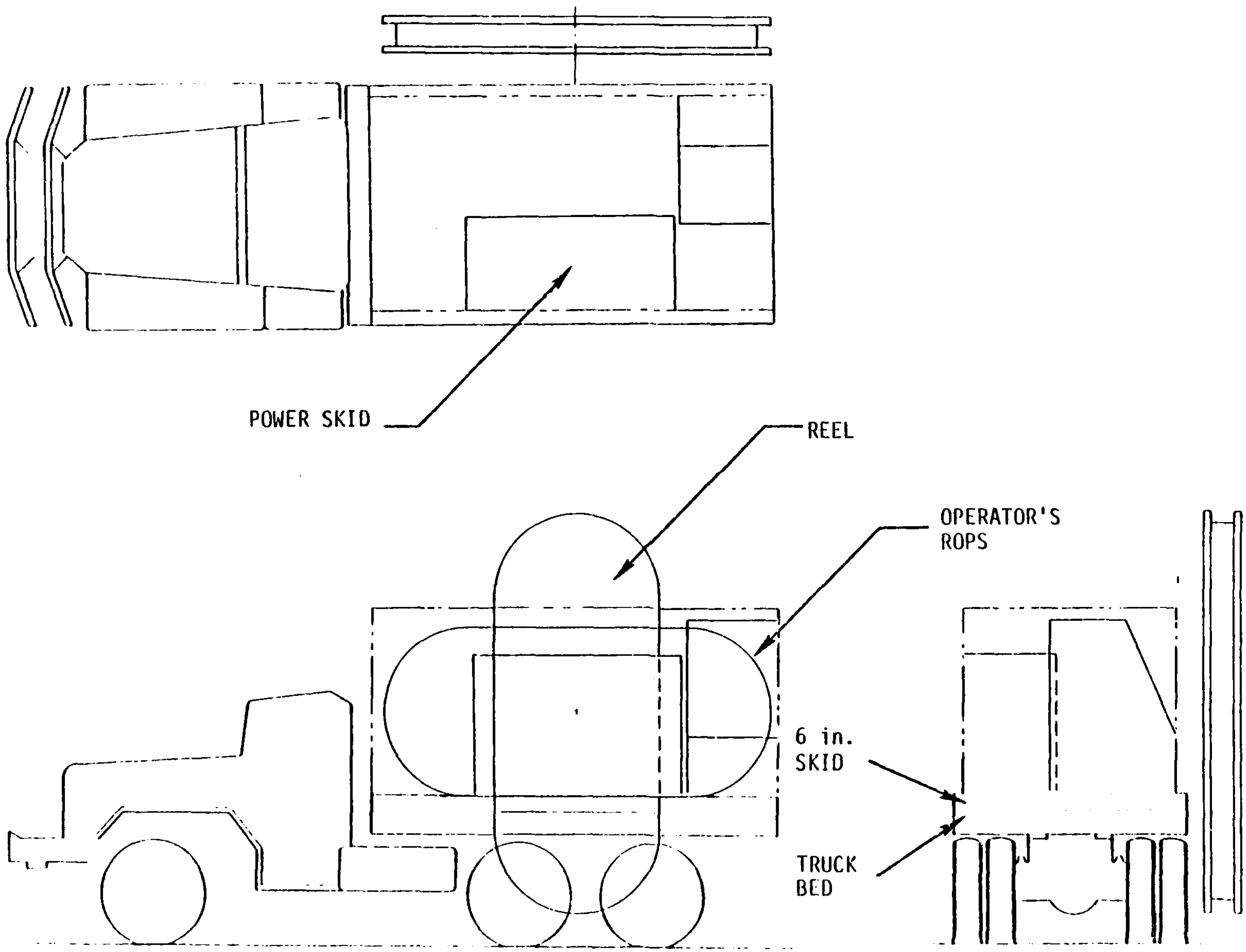


Figure 17. 500 ft oval reel.

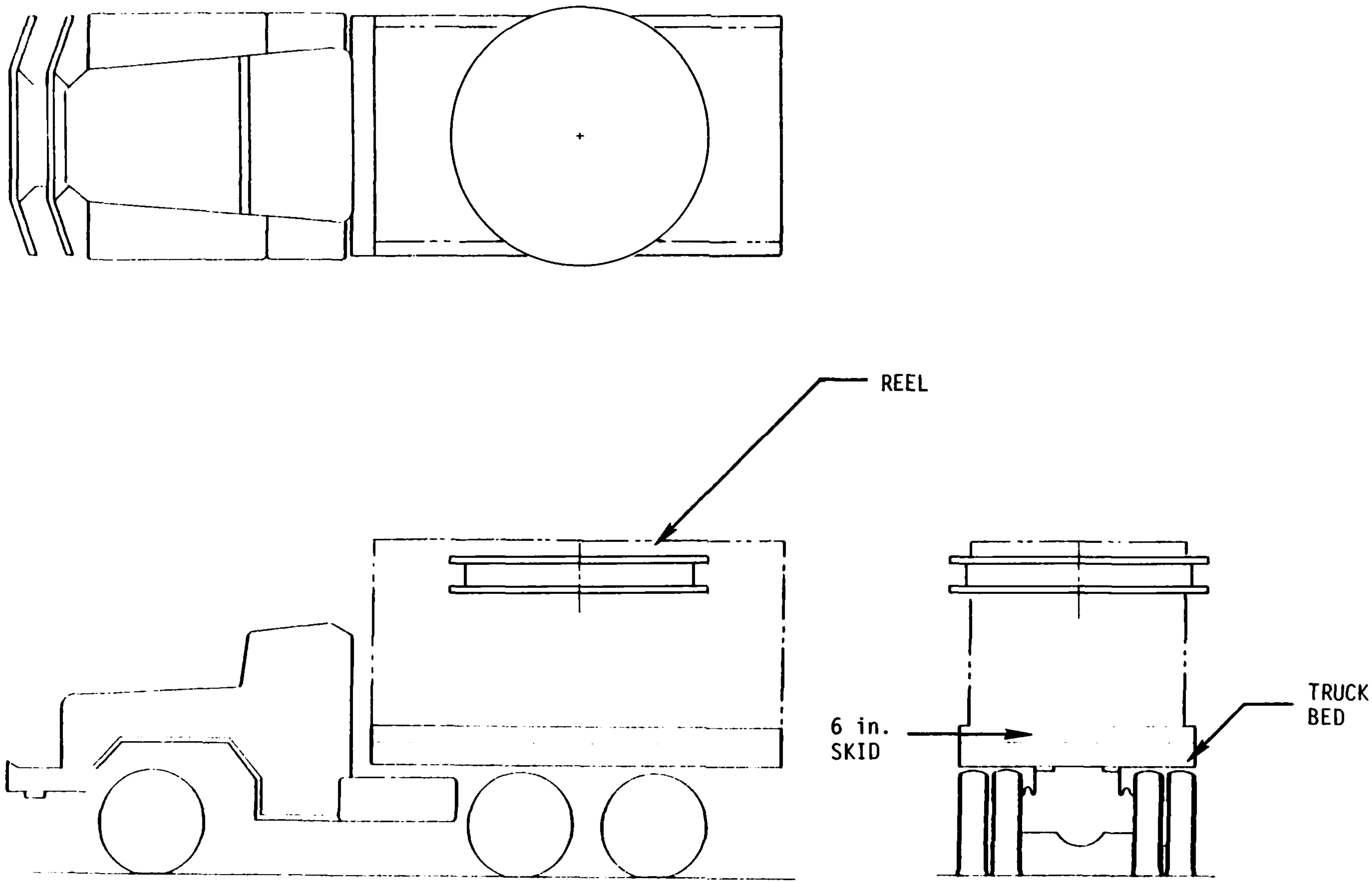


Figure 18. 500 ft single-wrap reel vertical axis.

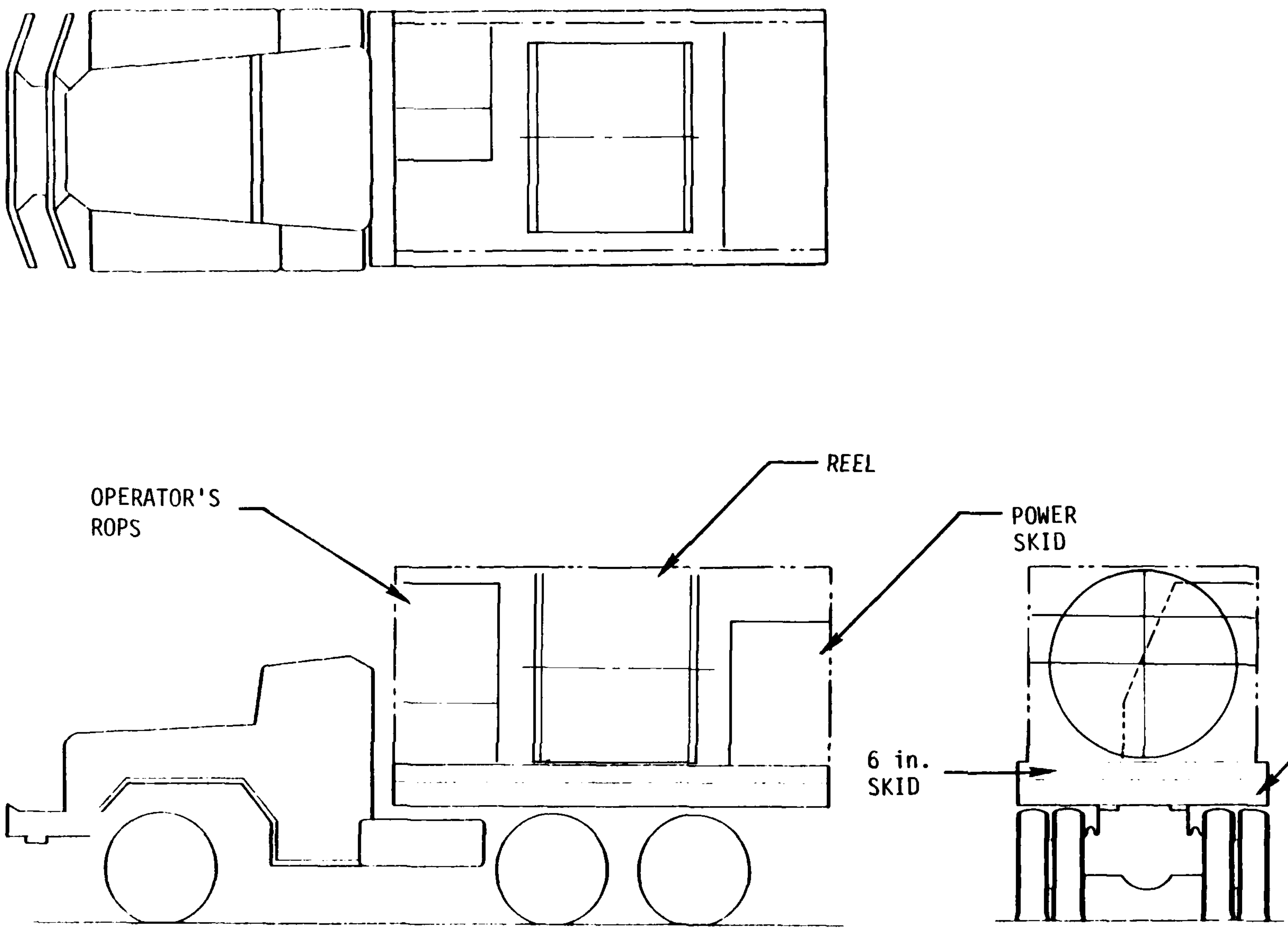


Figure 19. 500 ft multi-wrap reel lengthwise on truck bed.

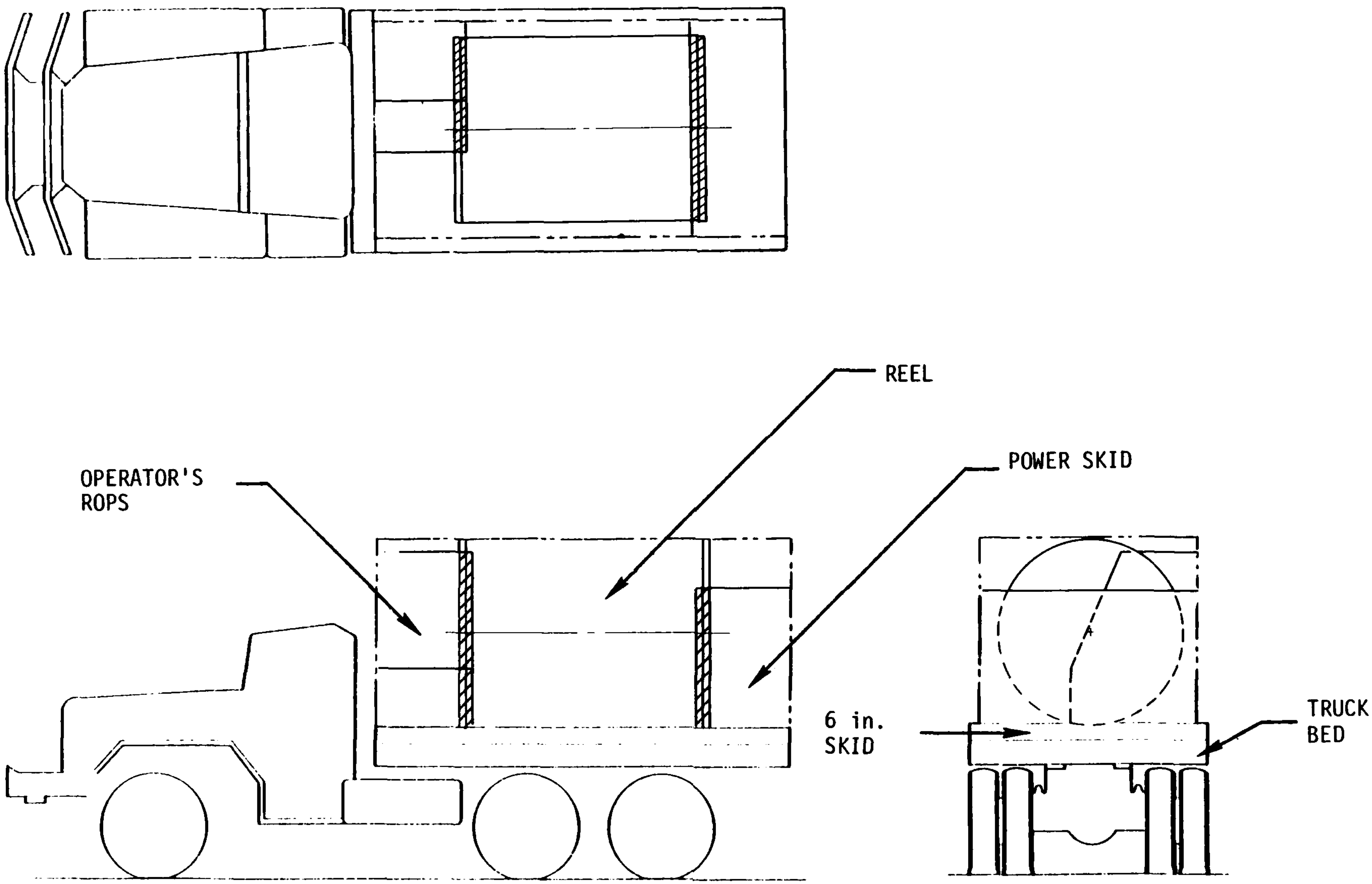


Figure 20. 1000 ft multi-wrap reel.

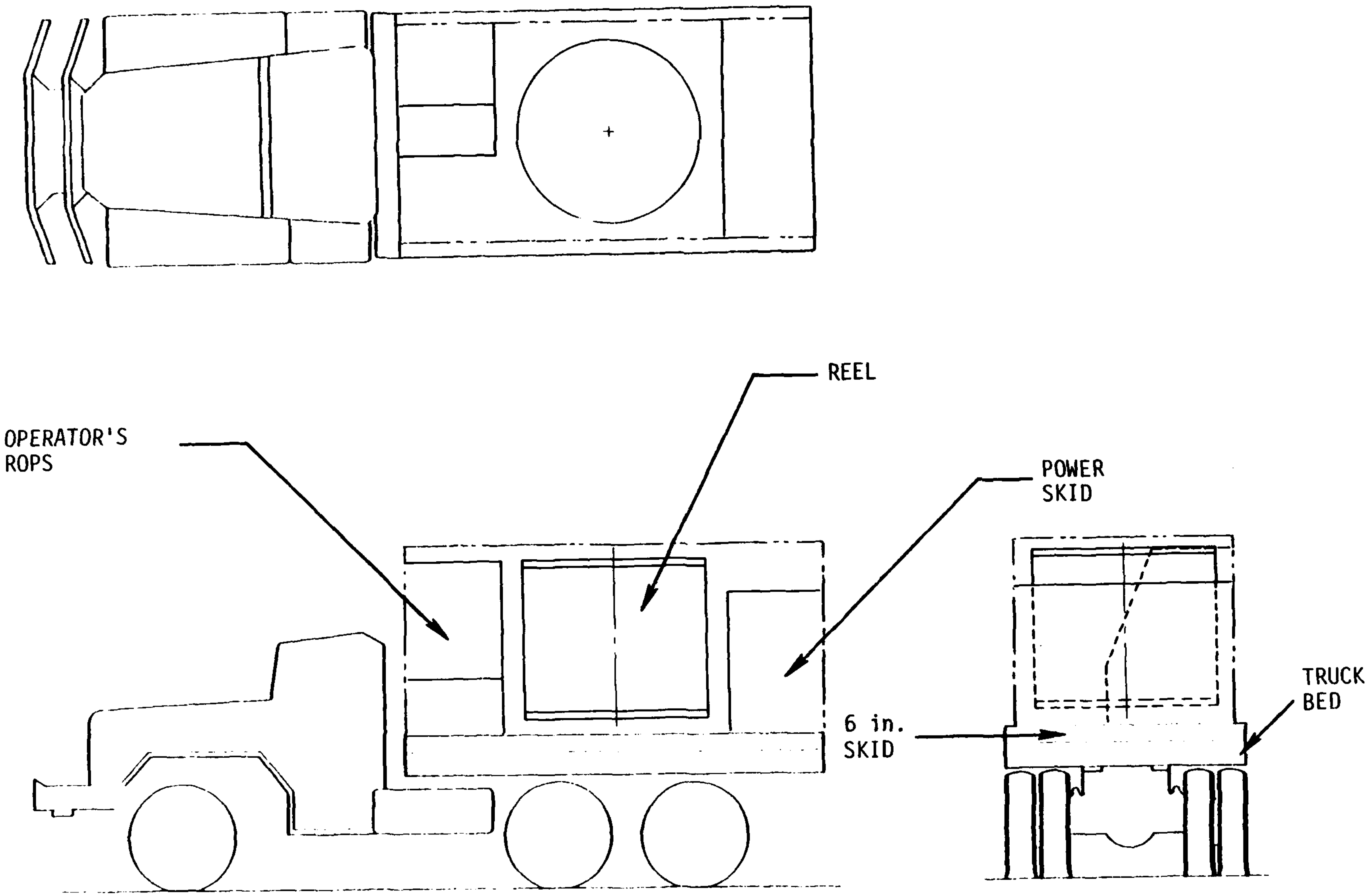


Figure 21. 500 ft multi-wrap reel on vertical axis.

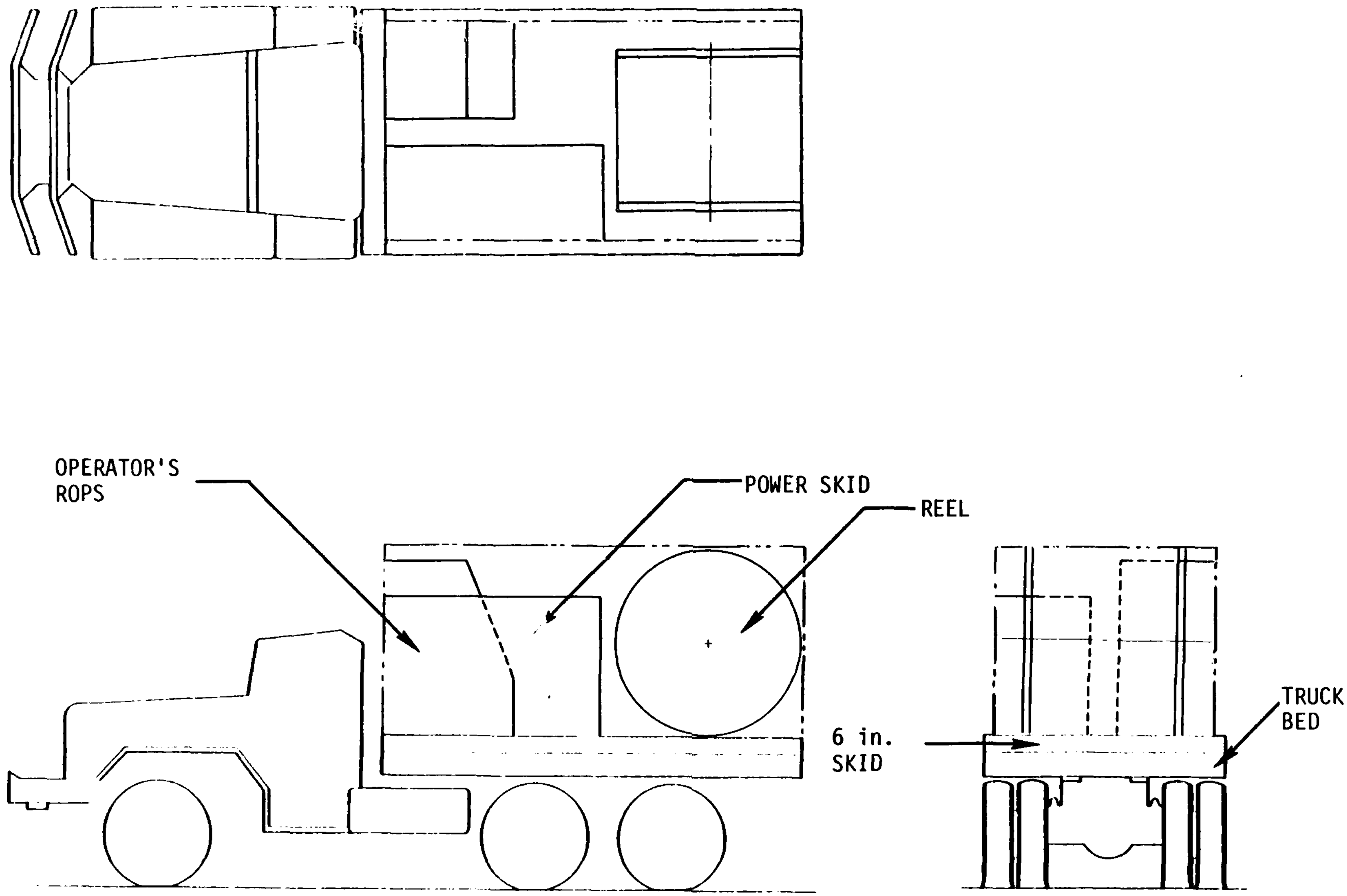


Figure 22. 500 ft multi-wrap reel across truck bed.

at the design review was made. This was based on several factors, all developed simultaneously. First, the single-wrap round reel could not be shipped in an ISO container. As this was a necessity, the round single-wrap was eliminated.

The highest-scoring remaining skid concept was the single-wrap oval reel. It, however, required clearance greater than 11 ft vertical to rotate, and would present problems in passing through bridges, tunnels, and the like. Its inherent simplicity dictated that it be offered nonetheless, for it minimized hose handling and was simple in construction.

To provide for the possibility that the clearance problem would be judged critical, the best scoring multiwidth concept was developed for comparison. Its development at the time of the first design review is shown in Figure 23. The competing design was Figure 24, the oval reel concept.

With the evolution of the two concepts, the inital concept development was presented to MERADCOM for critique. The outcome of that meeting was a new concept which became the concept implemented in the detail design phase. The revised concept's genesis is described in the next subsection.

3.4 The First Design Review

In December 1980, the design team presented their concept studies to MERADCOM for critique. In the course of the discussion, the simplicity of the single-wrap reel concept was judged highly desirable in making a reliable machine. The requirement to provide a minimum of 500 ft of hose on each reel was relaxed to stimulate discussion. This led to the observation that shorter hoses increase the time to lay a hose, because more reels must be moved. Putting more than one piece of hose on a reel would remove this constraint, however.

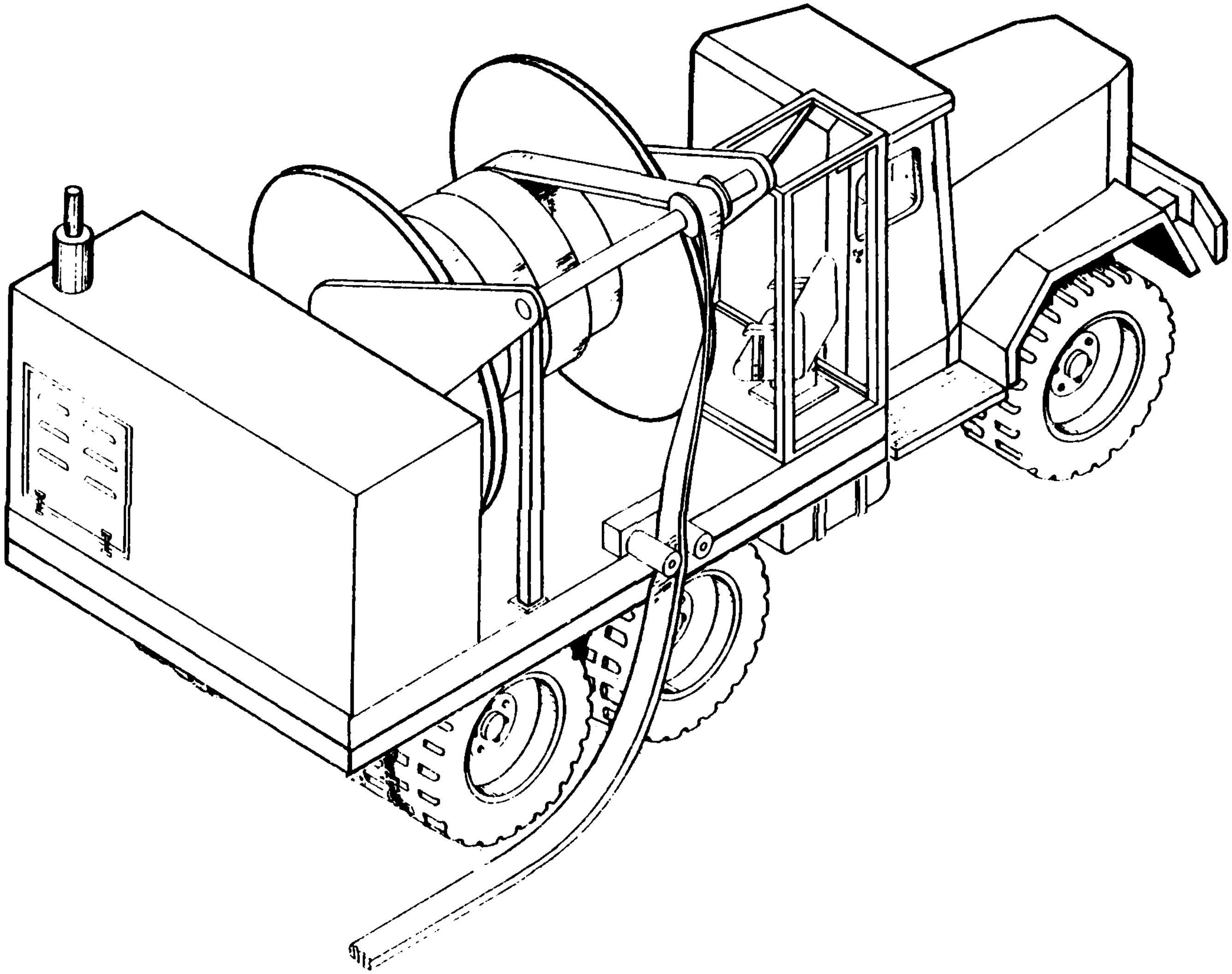


Figure 23. System concept with multiwidth reel.

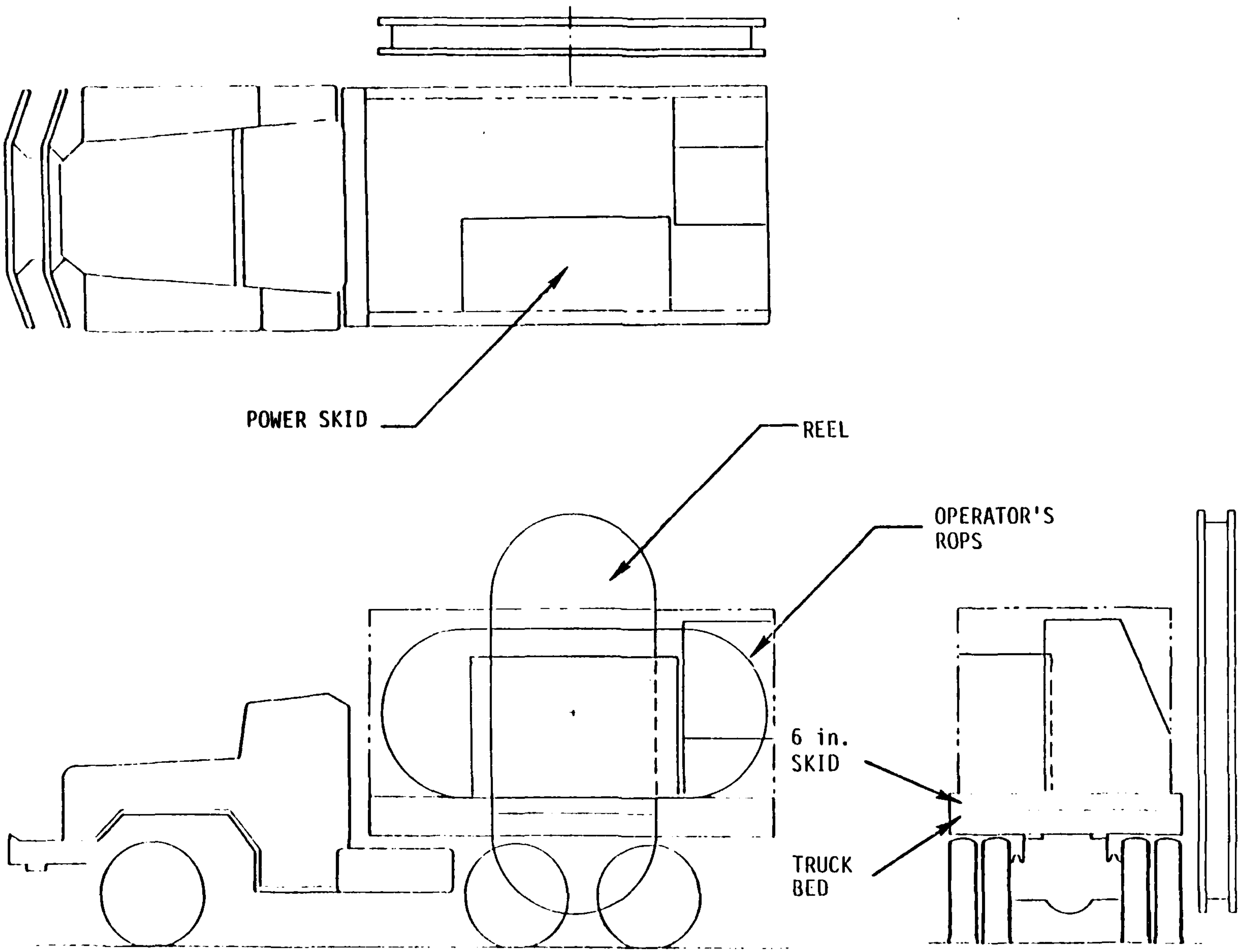


Figure 24. 500 ft oval reel.

Gradually, a new concept evolved which had the simplicity of a single-wrap reel combined with the storage capacity of the spiral-wound reels. It was, in retrospect, a derivative of the third and fourth scored skid concepts - a vertical axis group of single-width reels. The first concept drawing generated is shown in Figure 25.

The growth of the unexpected concept necessitated a period of study to find the most practical configuration for the idea. A second design review was ultimately required to solidify the concept and allow for detailed drawing to begin. The following subsection describes the evolution of the final concept.

3.5 Resolution of the Final Concept

Immediately after the first design review, a series of four variants on the new concept were laid out for analysis. At this time, the primary design emphasis was on maximizing operator and crew efficiency.

The first variant is depicted in Figure 25. Here, a crew of two men is required to operate the equipment. The skid operator could only lay hose from his position in the right front corner of the truck bed. A second man was required to mount the rear platform to change reels and thread the hose over the laying rollers. The concept as developed was collapsible to the length of the existing M813A2 truck bed for road transport.

To improve crew efficiency, a second concept was proposed. This is shown in Figure 26. Here, the hose loading and threading operation has been shifted forward to where the operator can perform this task in addition to laying the hose. This concept also could be contained within the length of the truck bed.

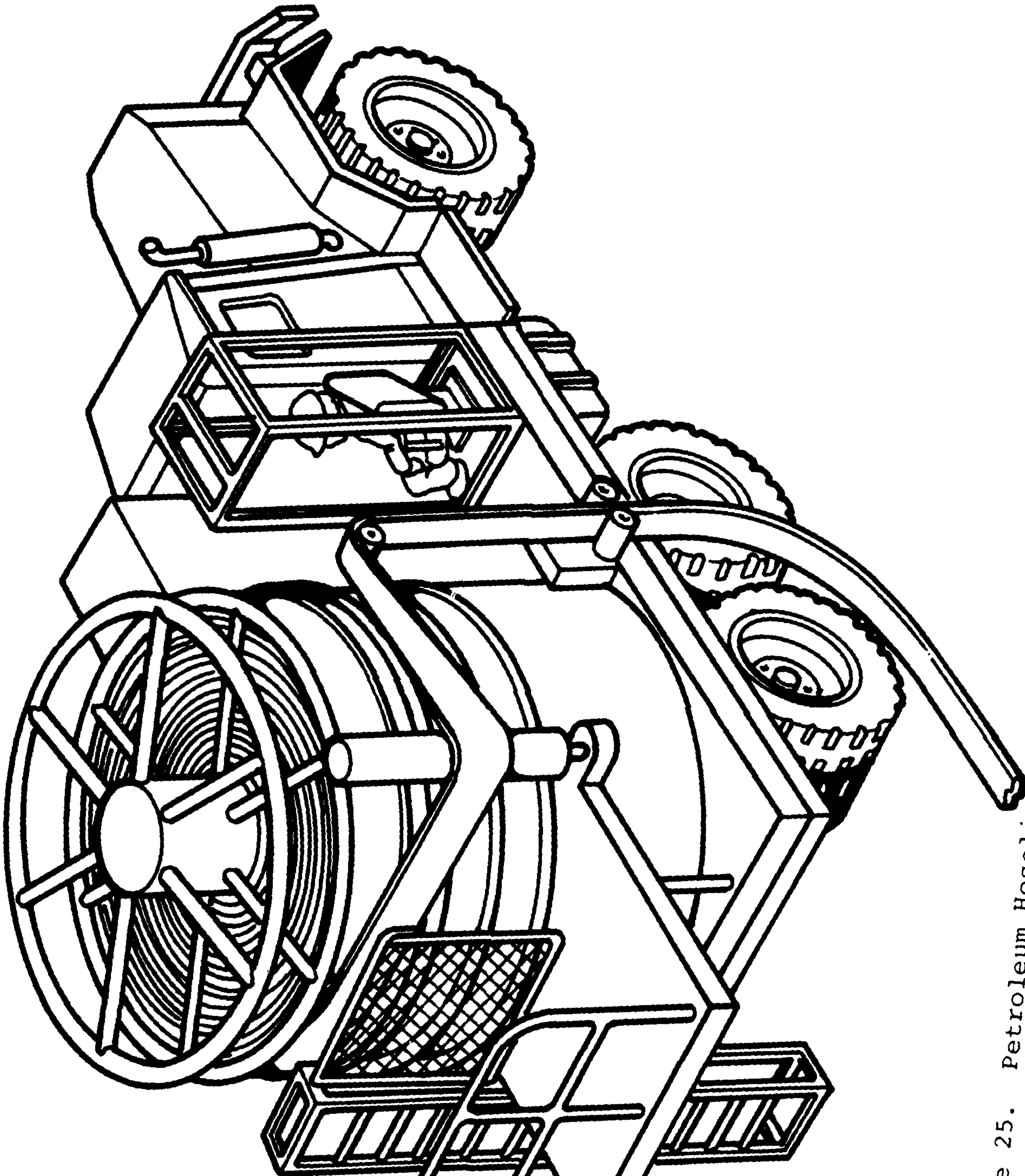


Figure 25. Petroleum Hoseline System truck skid concept no. 1.

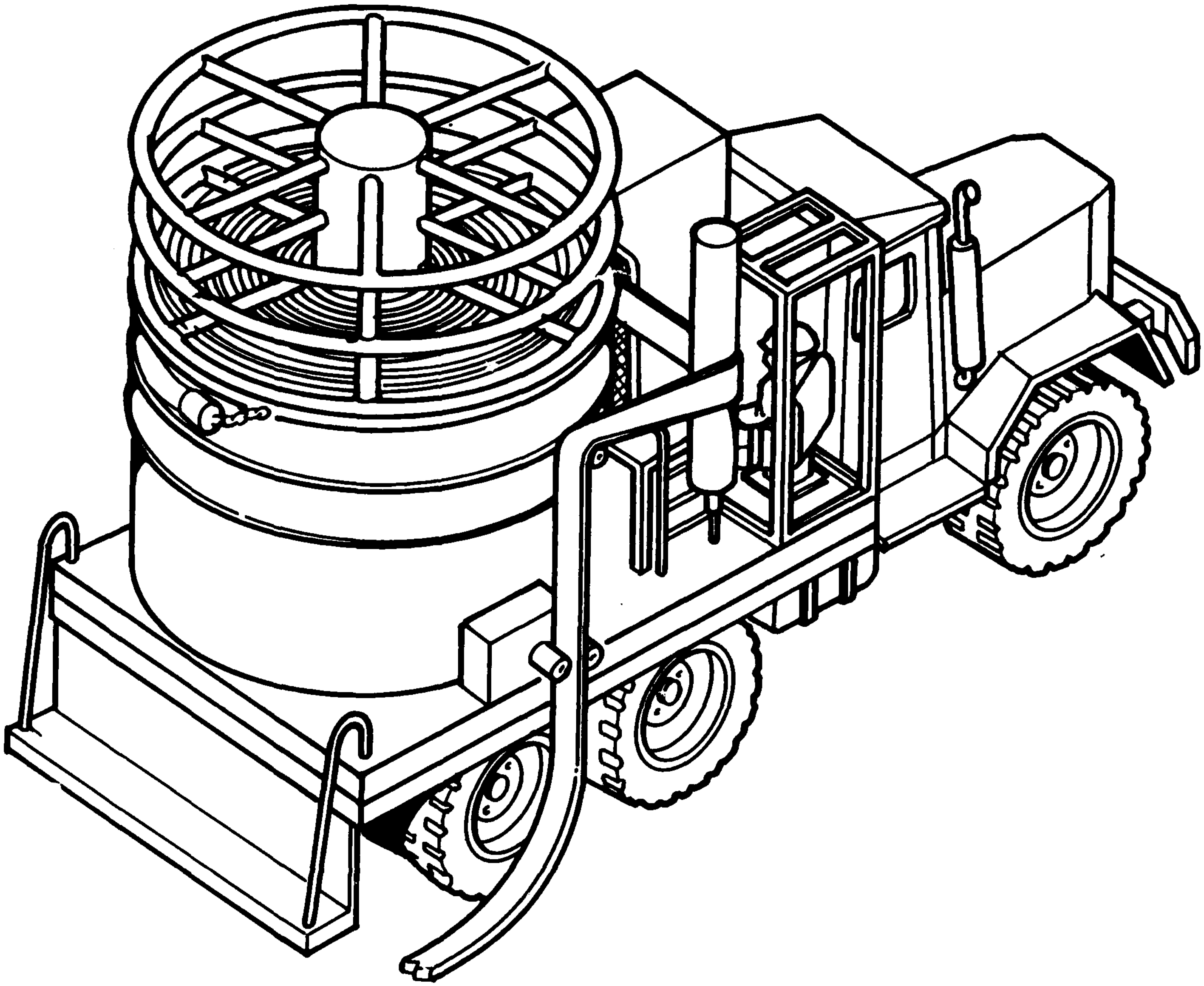


Figure 26. Petroleum Hoseline System truck skid concept no. 2.

Figure 27 shows a third variant proposed to get the skid operator away from the truck's exhaust stack and facing in the direction of travel, as opposed to sitting across the bed of the truck. This concept could not be contained in the length of the M813A2 bed, and required an overhang of around 1-1/2 ft. Furthermore, access to the engine was severely limited.

A fourth variant, shown in Figure 28, was finally developed to overcome some of the difficulties inherent in the third variant. The engine of the third variant is almost impossible to service if a reel is in place. In the fourth variant, the daily maintenance points are accessible through doors on the left side of the skid. Operator comfort in the fourth variant was thought to be improved by designing a standing operator's station so that the operator's legs would cushion him from the vehicle excursion that takes place so far from the pitch center of the vehicle. An overhang of 2 ft off the truck bed was necessary to implement this concept.

At a second design review, held on 27 April 1981, the merits of the four concepts were discussed. The variants of Figures 26 and 28 were presented as 1/8-scale models. The fourth variant, Figure 28, was selected as the preferred concept.

As a result of reductions in hose thickness achieved by Durodyne during their Phase I work, the preferred concept for the Hoseline Reel Assembly (HRA) was judged capable of carrying and deploying four 500-ft hose lengths before changing reels. A performance capability considerably greater than that projected early in Phase I was thus achieved by the selected concept. During the concept development stage, a simplifying process also took place which reduced the complexity of the Hoseline Reel Assembly, improving its inherent reliability. Section 4 will describe the final design configuration of the HRA and discuss its capabilities.

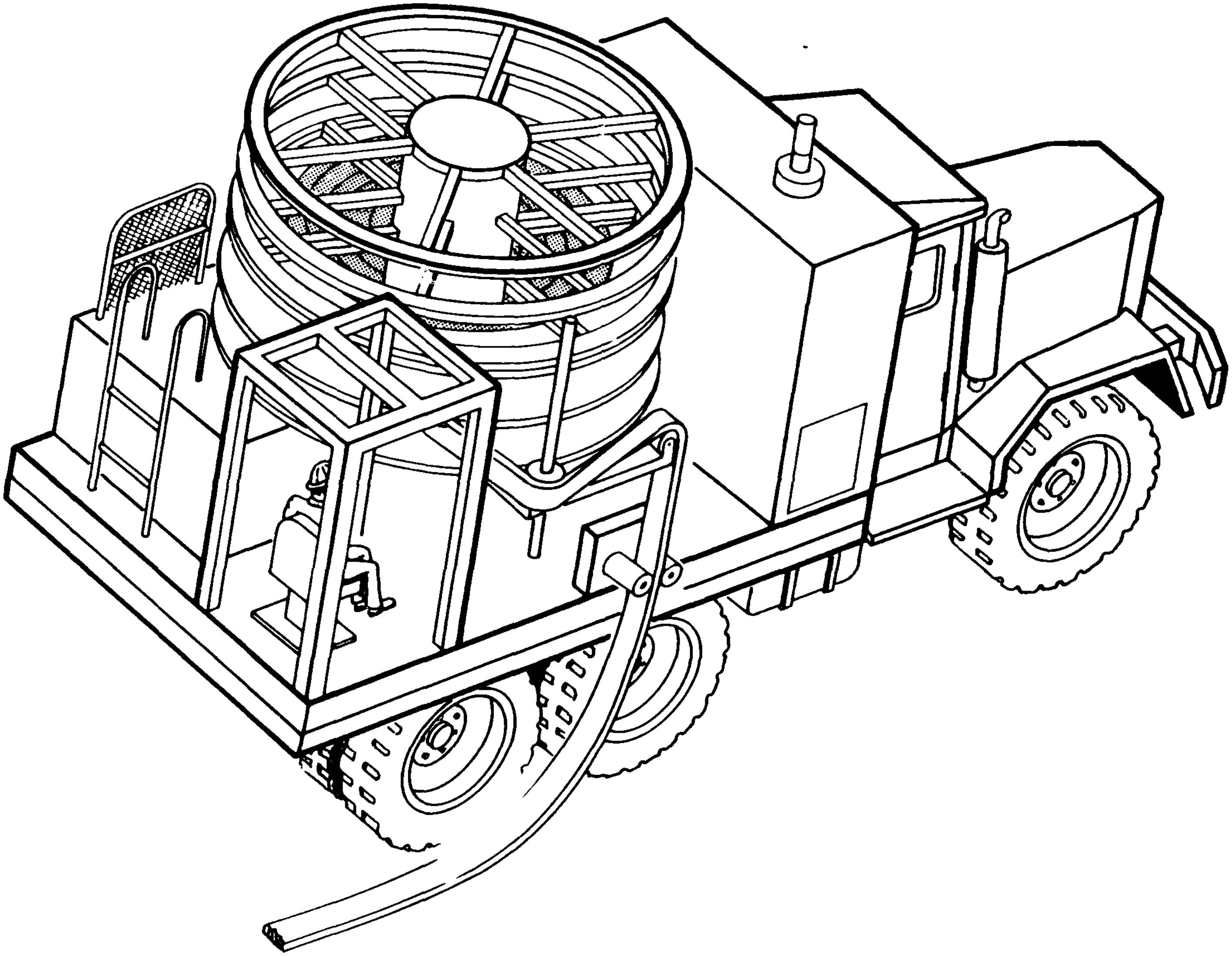


Figure 27. Petroleum Hoseline System truck skid concept no. 3.

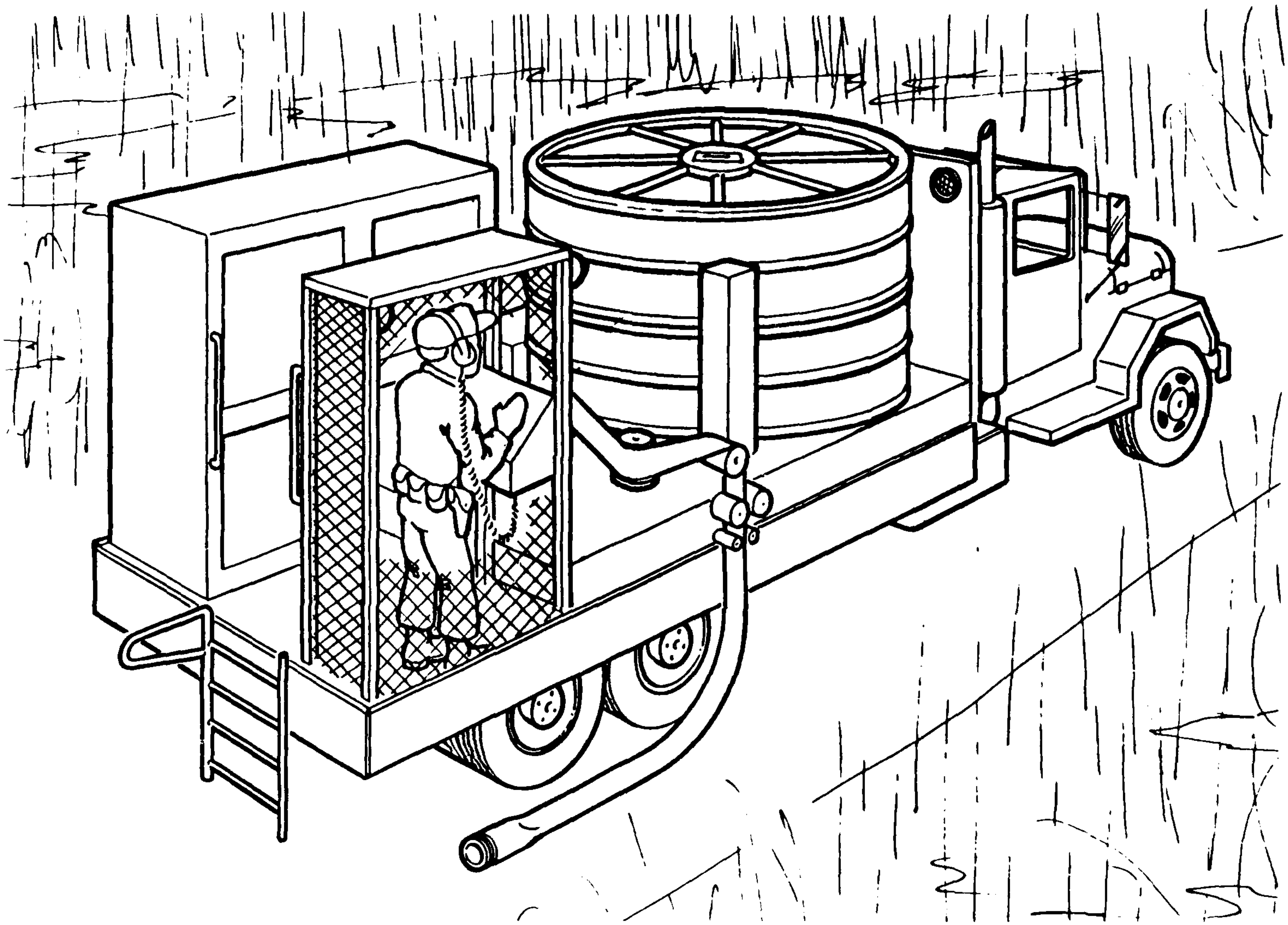


Figure 28. Petroleum Hoseline System truck skid concept no. 4 (final concept).

4. SUBSYSTEM CONFIGURATIONS FOR THE PETROLEUM HOSELINE SYSTEM

Once the concept configuration, which was shown in Figure 28, had been selected and approved, the various subsystem components could be detailed. The rest of Section 4 is devoted to a description of the final designs developed for these subsystems. Design analysis numbers are provided at appropriate points in the narrative.

4.1 The Hose

The 6-in. petroleum hose developed by Durodyne, Inc., during Phase I of their subcontract is, of course, a major element of the Petroleum Hoseline System. The hoseline development effort is discussed in Section 9; only those features of the hose which impact the Hoseline Reel Assembly will be discussed here.

The final hose configuration weighs 2.75 lb/ft. The 2000 ft of hose carried on the Deployment/Recovery Device thus weighs 5500 lb, exclusive of couplings. As loaded on a reel, each end coupling consists of four major parts: an adapter, a clamp ring, a seal, and an end plug to hold a vacuum in the hose. The total assembly weighs 12 lb; thus, 2000 ft of hose requires 96 lb of couplings. The adapter is an aluminum cylindrical insert clamped into the hose with band straps. It is machined with grooved ends to interface with couplings and gaskets conforming to MIL-C-10387. A standard Victaulic(TM) seal is used. The coupling (or clamp ring) is a low profile aluminum split ring coupling having a uniform outside diameter. The internal dimensions of the coupling comply with MIL-C-10387. The basic end plug (shown in Figure 29 with other coupling components) has a circumferential groove machined in accordance with MIL-C-10387 to mate with the coupling clamping. The end clamp ring plug is fitted with a quick disconnect for attaching the air hose or an ejector and a D-ring which are not shown in Figure 29. The end plug provides the necessary sealing to ensure that the vacuum in the hose is maintained.

The collapsed hose, with vacuum of 15 in. of mercury, packs on the reel in layers approximately 0.82 to 0.85 in. thick. Packing is aided by the tensile force of up to 275 lb provided by the HRA. The tensile strength of the hose is in excess of 4000 lb to sustain its rated pressure of 150 lb/in.^{2}, so this is not detrimental to the hose.

4.2 The Reel

An important component of the Petroleum Hoseline System is the reel which carries the hose. It must satisfy a number of requirements. It must be strong enough to protect the hose in shipment and use and be as light as possible to improve handling and reduce the installed weight on the HRA. It must transmit the reeling torque to the hose and resist the gyroscopic forces imposed by the hose itself and transmit them to the turntable.

These gyroscopic forces are worthy of note. A loaded reel carries around 2750 lb of hose and has an outer radius of 42 in. Since the reels are stacked two high (described below), the bottom reel is required to transmit the effect of 5500 lb of hose into the turntable. The reel stack is a large vertical axis gyro spinning as fast as 100 rpm. Under a 1 rad/sec angular precession of the gyro, as might be introduced by truck pitch or roll, the resulting gyro induced torque will be on the order of 14,000 ft-lb about an axis orthogonal to both the rotation of the gyro and its precession.

The number is significant for two reasons: first, strength of components, and, second, lateral truck stability. Strength of components is self-explanatory. Truck stability on a 15-deg side slope has been calculated to be on the order of 18,000 to 20,000

Figure 29. Coupling parts.

ft-lb. Thus, the gyro force is large enough to be sensed by the HRA operator and the truck driver, and perhaps large enough to affect mission performance.

It should be noted that the 14,000 ft-lb torque is a worst-case situation, reflecting the simultaneous occurrence of a full reel load, a 100-rpm reel speed, and a 1 rad/sec precession rate. All other anticipated gyro induced loads are lower than this.

The final reel design provided the strength necessary to withstand the forces anticipated. Each reel consists of a 24-in. diam hub and three 84-in. diam spoked flanges that are spaced 12 in. apart to provide slots for wraps of hose. (The slot width was increased from 10 in. to 12 in. during DT-1 testing as discussed in Section 8). Each slot will accommodate a wrap of up to 500 ft of hose. A rectangular steel tube, incorporated in the center of the hub includes provisions for latching reels together and latching the reel to the turntable. An attachment point for single point lifting of the loaded reel in a horizontal position is provided in the rectangular tube. The lifing point is designed for lifting up to three reels locked together.

A pocket for nesting the adapter and coupling fittings is incorporated in the hub as shown in Figure 30. The improvement in packing density that is possible with the Durodyne coupling is depicted in Figure 31. Also, the lack of a sharp bend in the hose as it conforms to the hub is shown in this figure. Essentially, the unavoidable distortion of the hose where it meets its adapter is utilized to make the transition to the hub efficiently. The sharp reverse bend common in flaking a hose for storage is missing. This should prolong the hose storage life.

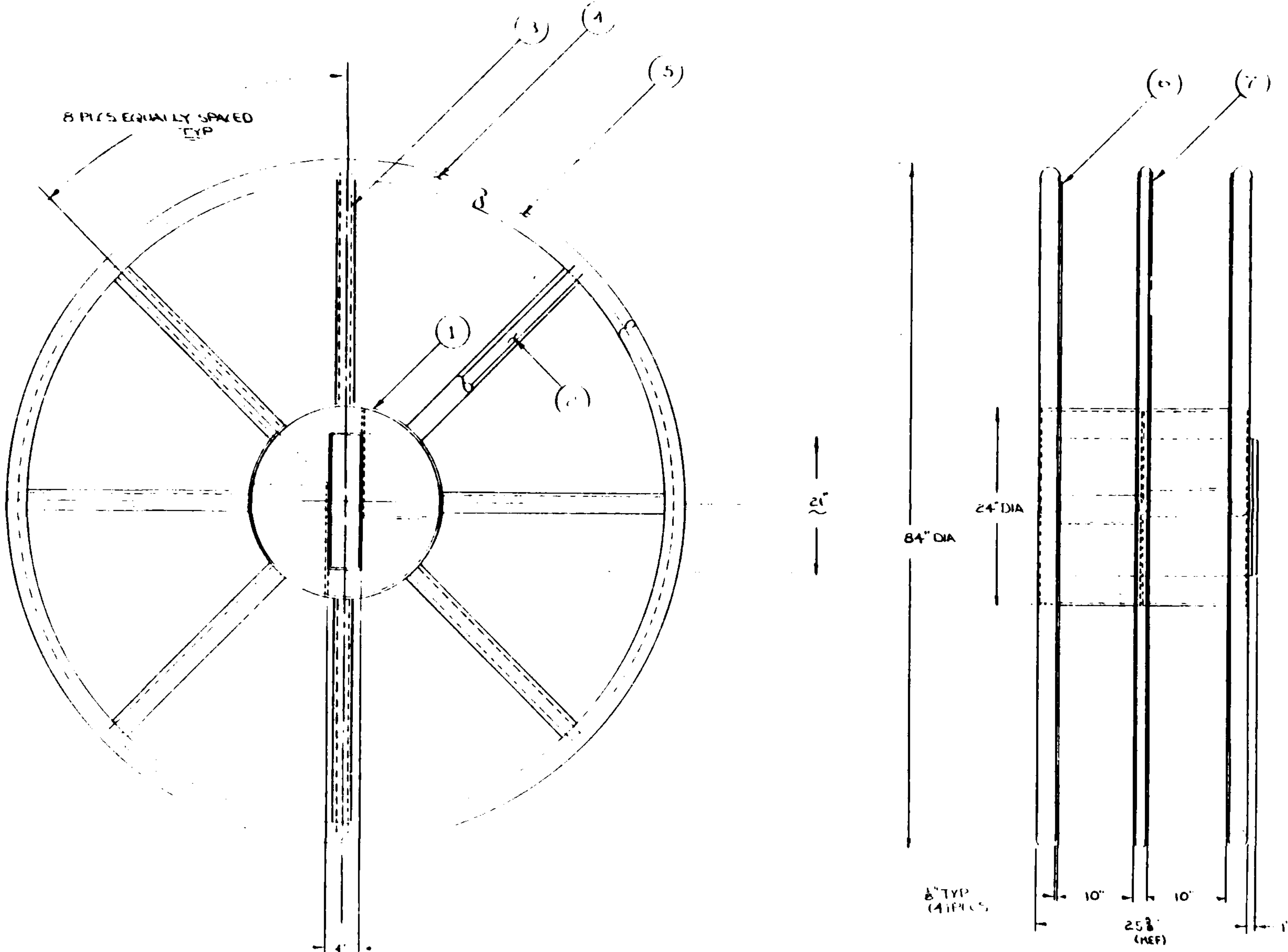


Figure 30. Reel assembly.

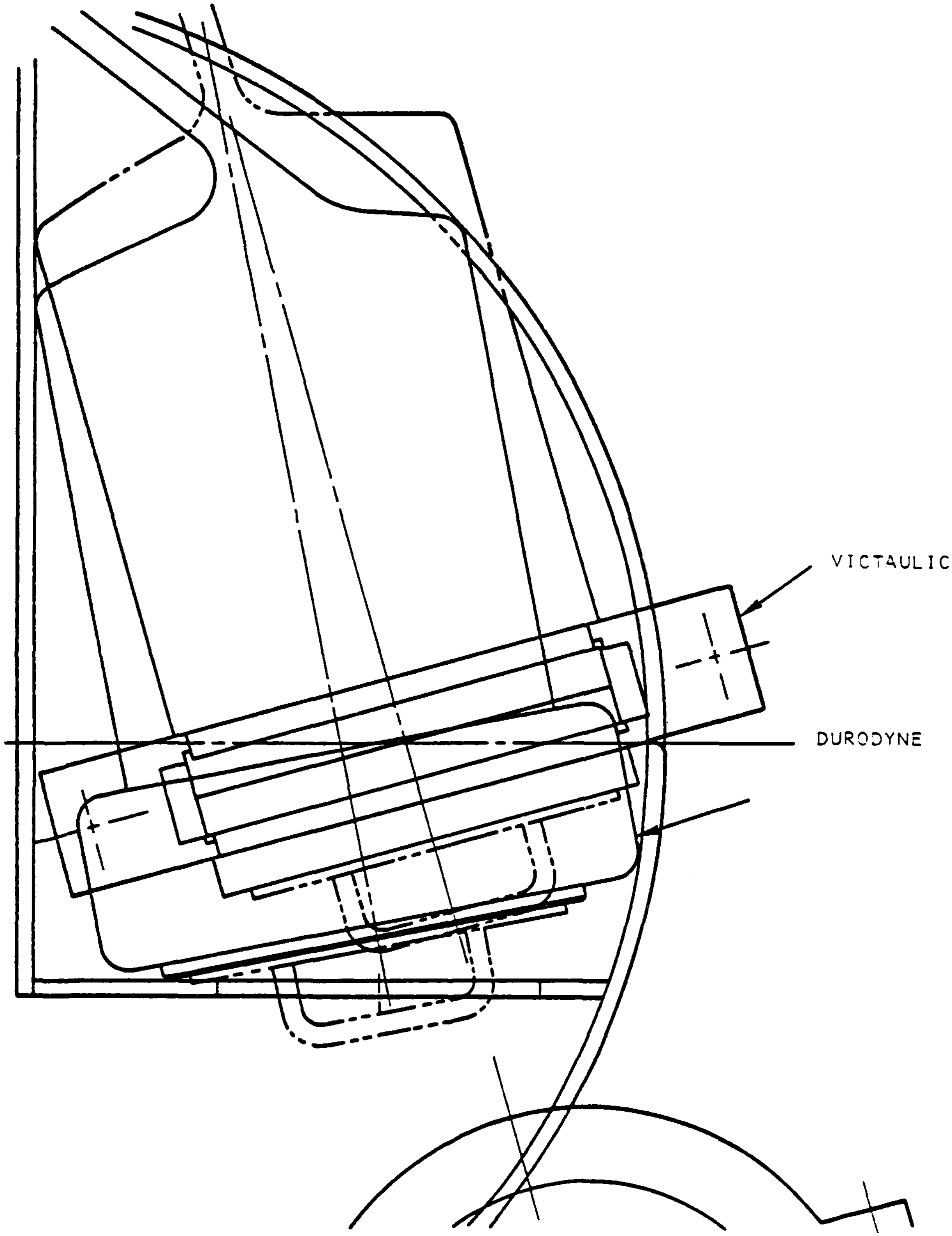


Figure 31. Victaulic versus Durodyne coupling.

The reel flanges are of tubular construction to save weight. Since each reel is installed on the turntable hub only one way (same side down all the time), thin perforated sheet metal has been added to the flange surfaces where the hose rests.

To save space, the reel flanges end at the expected diameter necessary to store 500 ft of hose. The outer coupling is lashed to the reel with a retaining strap. The end condition is shown in Figure 32. With this construction, it was possible to build a reel holding 500 ft of hose that would fit through the cargo door of an ISO standard shipping container. The two hose couplings are simply oriented away from the door edge during the insertion and removal process.

It is important to realize that centrifugal force is a factor in selecting the strap to hold the end of the hose to the reel. The hose end and first 180-deg wrap of hose induce loads of 200 to 250 lb in the direction tangent to the rim at rotational speeds of 100 rpm. A substantial strap is indicated. During operation, the strap must be installed properly, too, to prevent the hose coming loose during deployment or recovery of subsequent hoses.

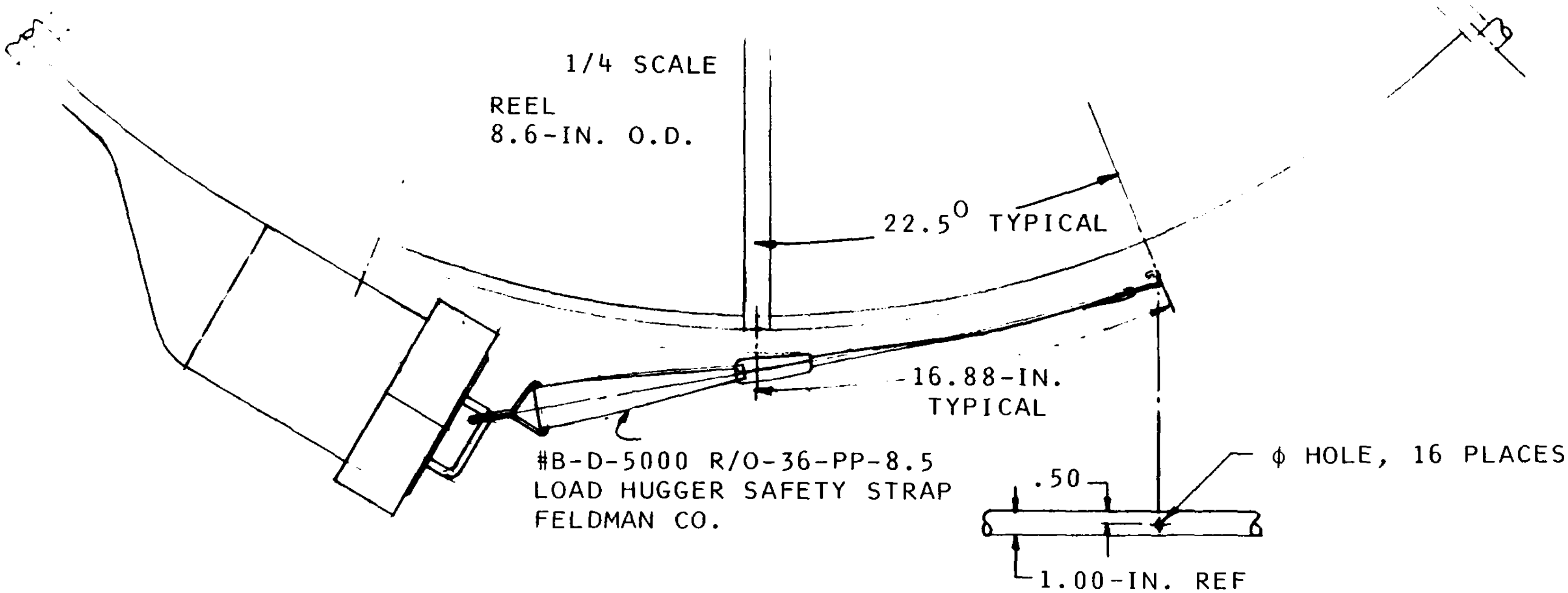


Figure 32. Hose end tie down system.

4.3 The Turntable

The turntable and its drive are key elements of the HRA. This assembly drives and supports the reel stack and must resist all of the gyroscopic forces discussed in the reel section. A low-profile Keene MTO 265 turntable bearing is the principal support for the turntable. It reacts the loads down into the frame weldment. The radial piston low speed hydraulic motor that drives the turntable is isolated from all forces except the reeling torque by this bearing.

The Sundstrand motor is capable of producing 1500 ft-lb of torque at 1500 $lb/in.^2$. This is adequate to accelerate the reel fast enough to follow the truck as it accelerates to lay or recover a hose. The torque capacity includes a provision for maintaining up to 275 lb of tension in the hose at all times.

The turntable assembly is shown in Figure 33. The large tapered post is the drive key which fits into the rectangular socket of the reel. Four pawls are spring-driven into slots in the reel socket to lock the reel to the turntable automatically. The taper facilitates the reel's dropping over the post on uneven ground during a reel change.

A foot pedal is provided to release the pawls while lifting off a reel. The pedal must be held depressed while the lift is made. Upon release of the pedal, the pawls reset under spring force, ready to receive another reel.

4.4 The Engine Enclosure and Power System

Contained within the engine enclosure is the power system for the Hoseline Reel Assembly. Power is derived from a GMC

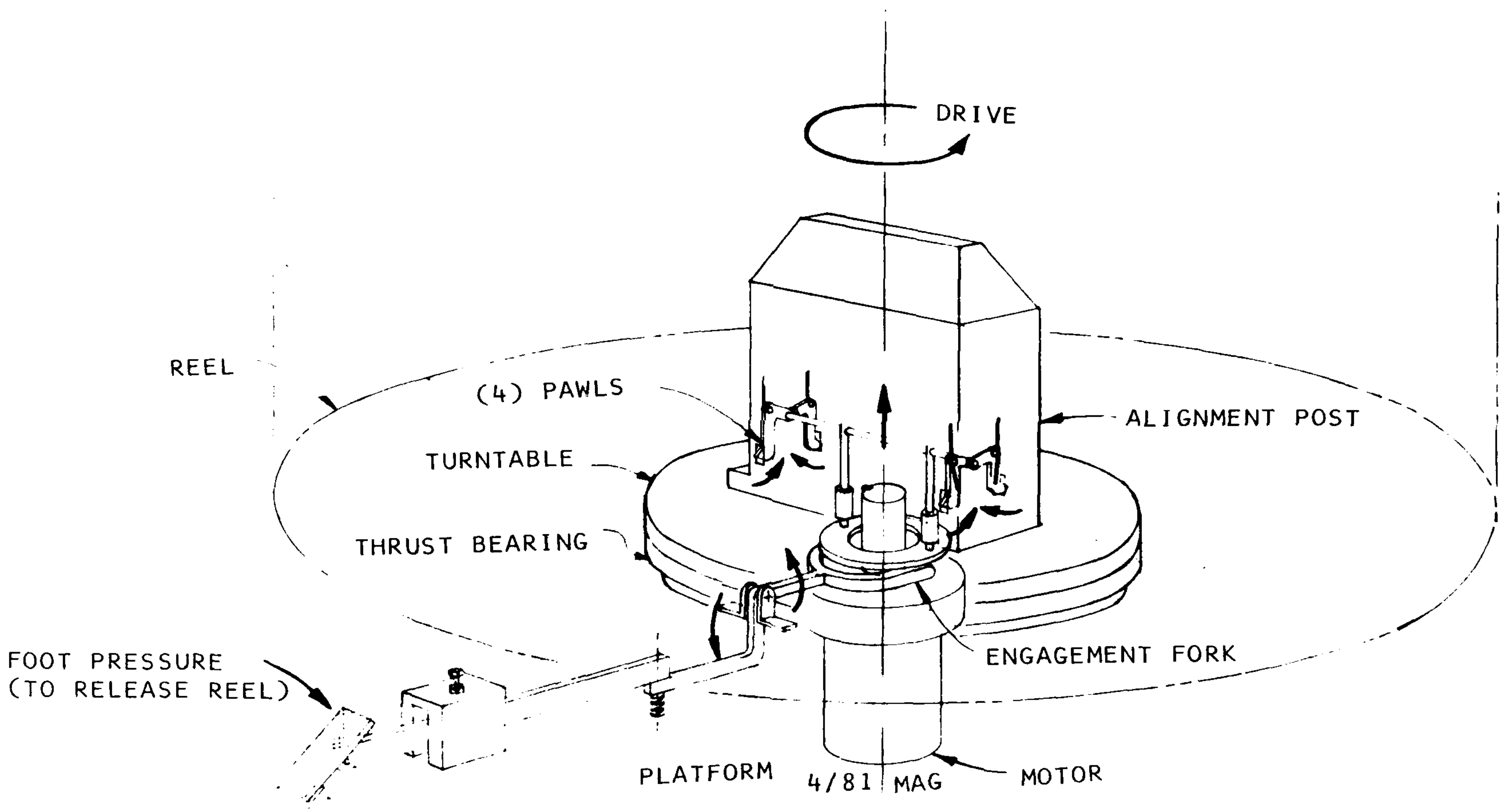


Figure 33. the turntable assembly.

Detroit Diesel 353 engine. The diesel powers a Sundstrand Model 22-2074-LHROT variable volume hydraulic pump and a Quincy air compressor through a Funk Model 28102 gear drive unit. The hydraulic pump is joined to the turntable drive to create a closed loop, high-efficiency reel drive. The air compressor, isolated during reel drive operations by a hydraulic clutch, can be operated to provide air to purge the hoseline of fuel. The air is also used with a Penberthy GL-1 ejector to pull a vacuum on the hose to collapse it for recovery.

The GMC diesel is operated at 1200 rpm to facilitate noise control. Approximately 30 hp is available at this point on the power curve. Specific fuel consumption is approximately 0.44 lb per brake horsepower hour. The engine is equipped with two sets of controls for reliability. A set of manual controls, adequate to enable engine monitoring and shutdown from the service platform, is provided within the engine enclosure (described below). Oil pressure and water temperature gauges are provided for maintenance evaluation.

A second set of automatic and electric controls are provided which are sufficient to operate and protect the power plant from the operator's station on the Hoseline Reel Assembly. Automatic low oil pressure and high coolant temperature shutdowns are provided. An electrically operated fuel cutoff is provided for normal engine shutoff. An electrically operated air cutoff is provided for panic shutdown of the engine.

This air cutoff is wired to a panic button on the operator's console. Because the cutoff must be reset manually within the engine enclosure, this panic button on the console should not be used as a substitute for the normal shutdown procedure.

An electrically operated throttle is provided to synchronize the engine speed to the work cycle. The throttle is a two-position control: idle and power. The engine has a governor to match power output to engine revolutions per minute setting (throttle setting). The throttle setting, or rather a variation of the throttle setting, is not a control provided to the operator directly. By selecting his desired mode of operation on his console, he gets the proper throttle position. This simplifies his console and ensures that adequate power will be available to meet demand.

Figures 34 through 37 show the configuration of the engine enclosure and its contents. In addition to the major items mentioned above, the enclosure contains a number of other essentials, such as the engine air cleaner, the engine silencer, and the hydraulic oil cooler.

Care has been taken throughout the design of the engine enclosure to provide acoustic attenuation to ensure meeting the specified requirement of 85 dBA noise level at the operator's station. As was mentioned earlier, the diesel runs at 1200 rpm to reduce noise. A special muffler, termed a hospital silencer, is used to cut exhaust noise. An oversize air cleaner is used to reduce intake air noise. The engine enclosure itself is a sophisticated acoustic enclosure.

All the side panels and the top of the enclosure are constructed as shown in Figure 38. A 2-in. thick acoustic attenuating foam is sandwiched between two pieces of sheet metal to absorb as much sound as possible. All openings on the enclosure are pointed away from the operator so that transmitted noise is not focused in his direction. The need for intake air and cooling flow

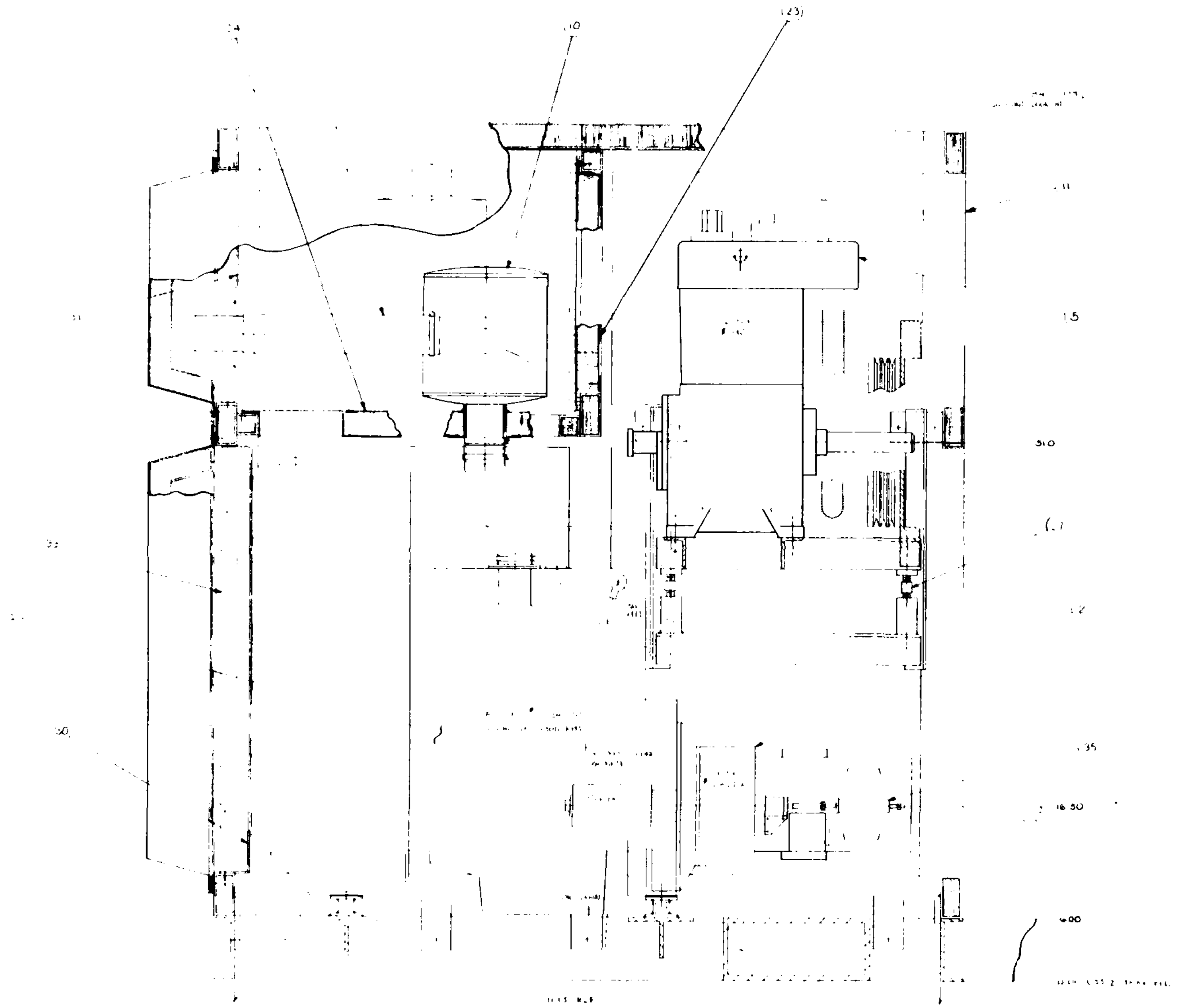


Figure 34. Cutaway of engine enclosure as seen from operator's station.

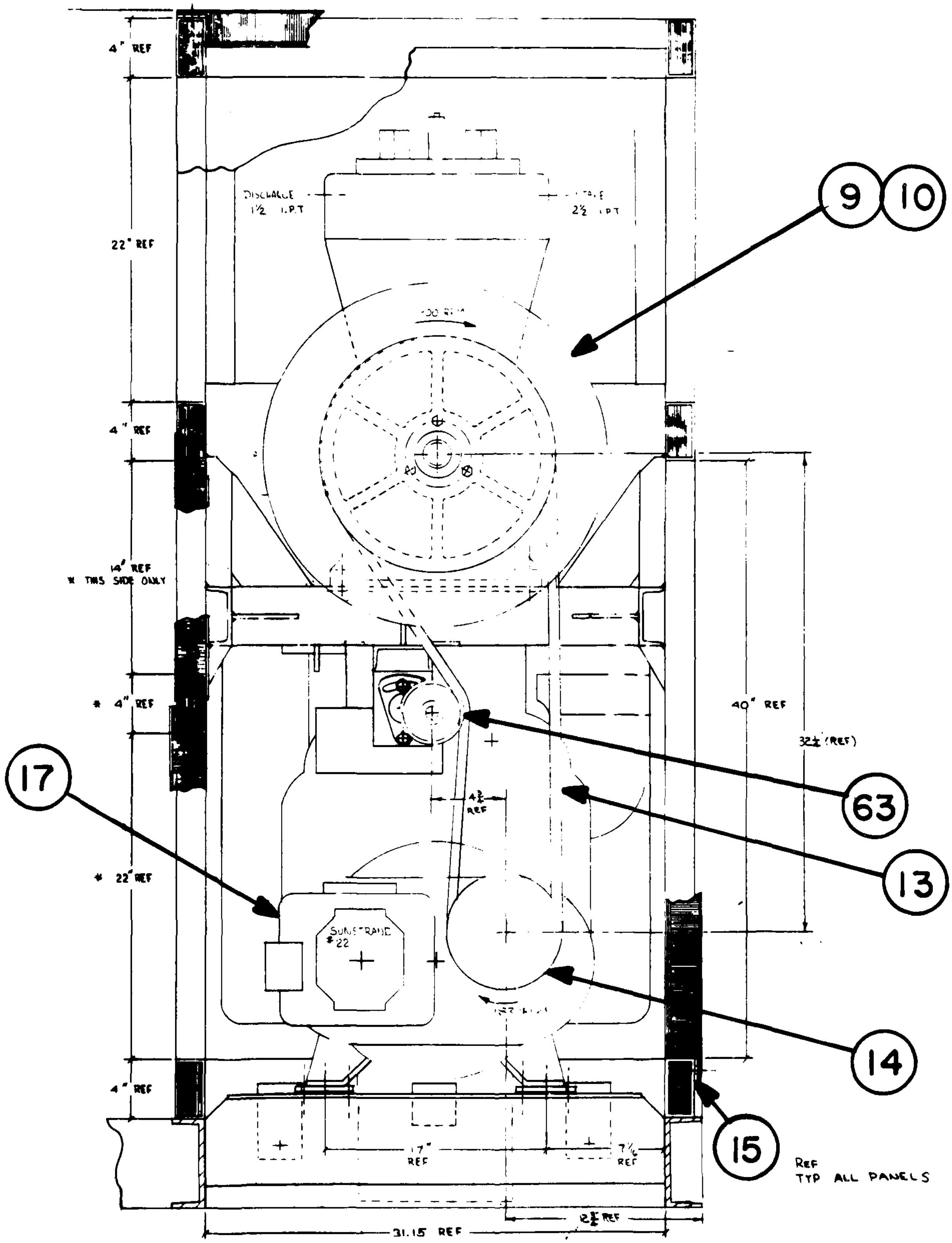


Figure 35. Cutaway of engine enclosure as seen from the reel.

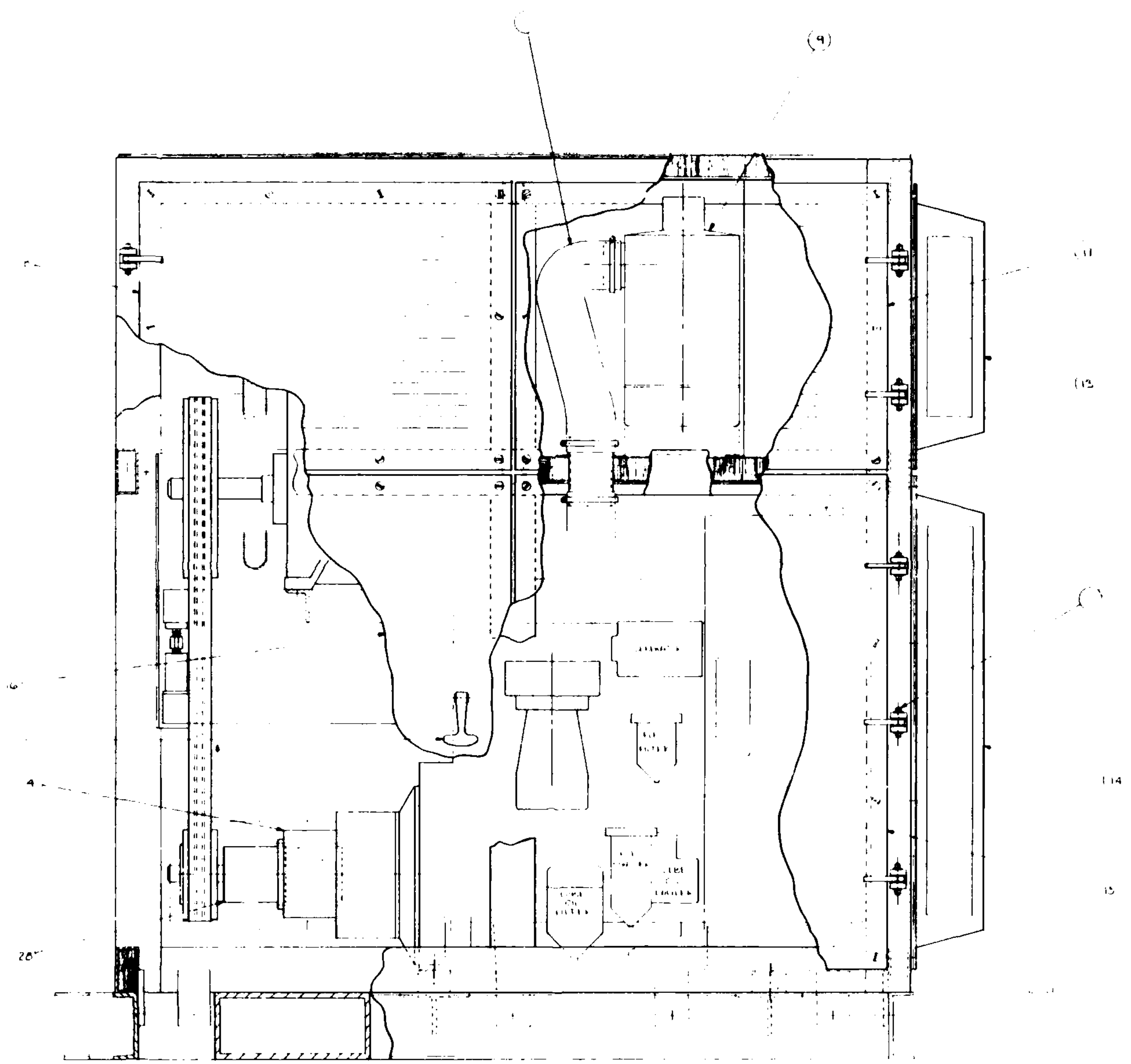


Figure 36. Cutaway of engine enclosure as seen from the service platform.

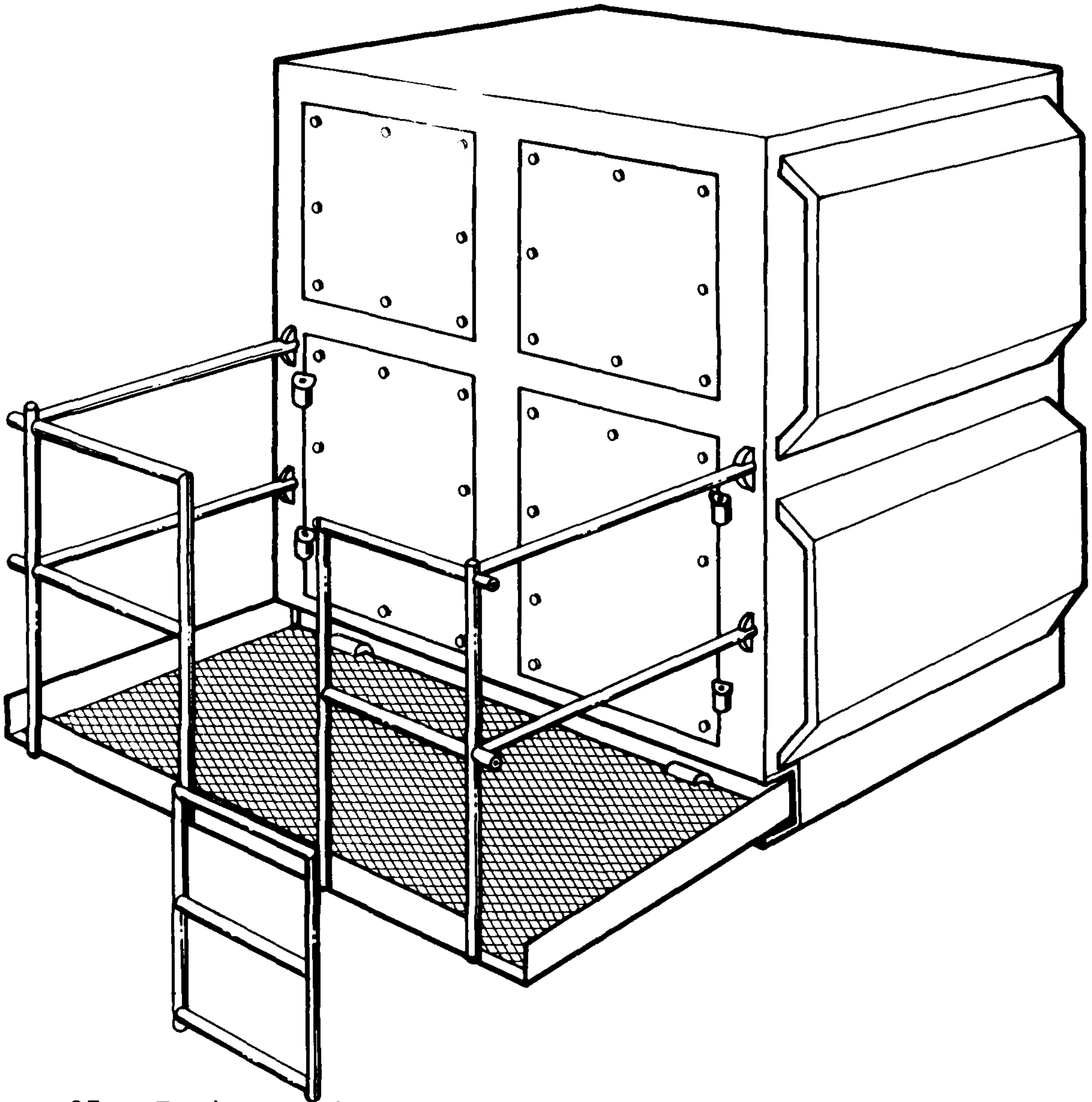


Figure 37. Engine enclosure with service platform in working position.

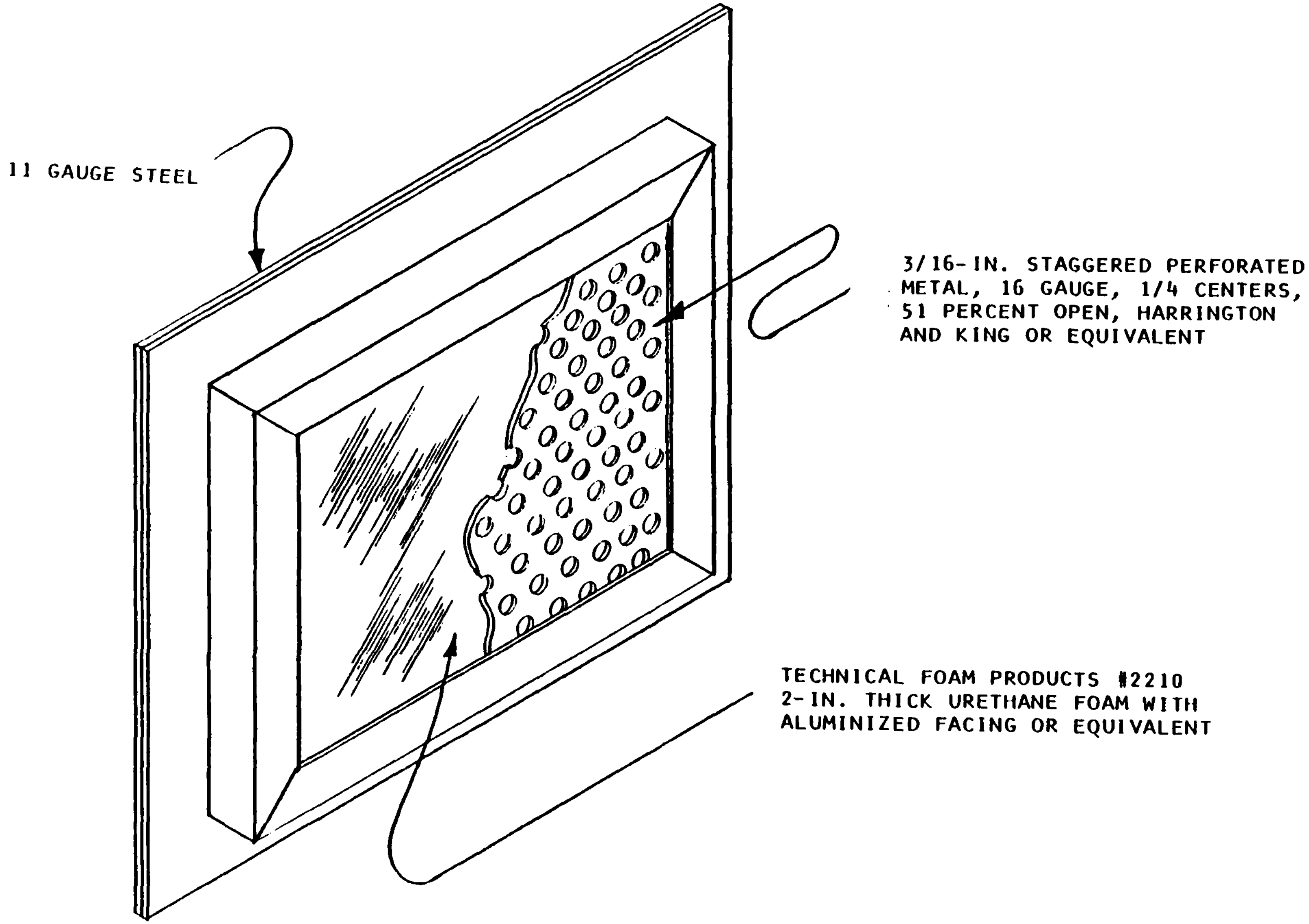


Figure 38. Typical panel construction.

prevents sealing the enclosure. At the recommendation of MERADCOM acoustic specialists, all air passages contain a right angle turn to make the acoustic absorption as effective as possible. As discussed in Section 8, the louvered openings for air flow should be modified to eliminate line of sight from the interior of the enclosure to the outside.

As a sidelight to acoustic treatment, MERADCOM personnel pointed out the desirability of a pusher fan for the engine, to ensure that warm cooling air exists the enclosure as quickly as possible. This reduces engine operating temperature, which is always desirable with a closely cowled engine. Consequently a pusher fan has been used.

To reduce structure-borne noise, the engine is mounted on sound absorbing pads.

With the acoustic treatment described above, the sound level at the operator's station was 89.5 dBA with the HRA engine running at 1200 RPM and the truck engine off. Futhermore, the engine tended to overhead during air compressor operations under high ambient conditions. Both of these problems may be corrected by modifying the air openings as described in Section 8.

A futher feature of the engine enclosure is shown in Figure 37. The routine service points on the engine, Funk box, and compressor must be made available for daily maintenance. Space utilization prevented access to these points from the operator's side of the engine enclosure. Therefore, a fold-down service platform was provided on the left side of the Hoseline Reel Assembly skid to perform maintenance. The components within the upper area of the enclosure can be accessed by removing the two upper enclosure panels. The two most frequently used lower panels are hinged for convenience. The platform is provided with guard rails and toeboards for safety and is constructed of aluminum for weight reduction. This allows a single soldier capable of lifting 30 lb to raise the platform into its storage position and secure it. The platform is rated for 300 lb live loads and is so marked.

4.5 Frame

The Hoseline Reel Assembly frame is a large structural weldment that serves as the mounting base for all other subsystems. For example, it seals the bottom of the engine enclosure to prevent sound propagation. It is the reaction base for the turntable, and transmits all the forces generated above the turntable down into the truck bed through the truck tiedown system. It is the base for such auxiliaries as the battery box, the hydraulic oil tank, and the fuel tank and supports the guide roll system which controls the path of the hose from the ground to the reel.

It incorporates overhead protection for both the truck driver and the HRA operator. This is principally for protection during the lift of the reel stack. It also provides brush protection for the operator by enclosing the operator's station with a large mesh screen.

The frame incorporates the lift and tiedown points for handling and transporting the HRA. A three-point lift system is built into the deck of the frame for lifting the HRA without the reel stack in place. The concept is shown in Figure 39. A three-legged sling, rated at 15,000 lb, is adequate to lift the complete HRA without reels. Four tiedowns are provided at the base of the HRA skid along each long side. The base of the frame is constructed with sled runner ends to prevent the HRA from hanging up as it is pushed into or out of a Milvan container. The operating decks are constructed of expanded metal mesh for good traction under all weather conditions.

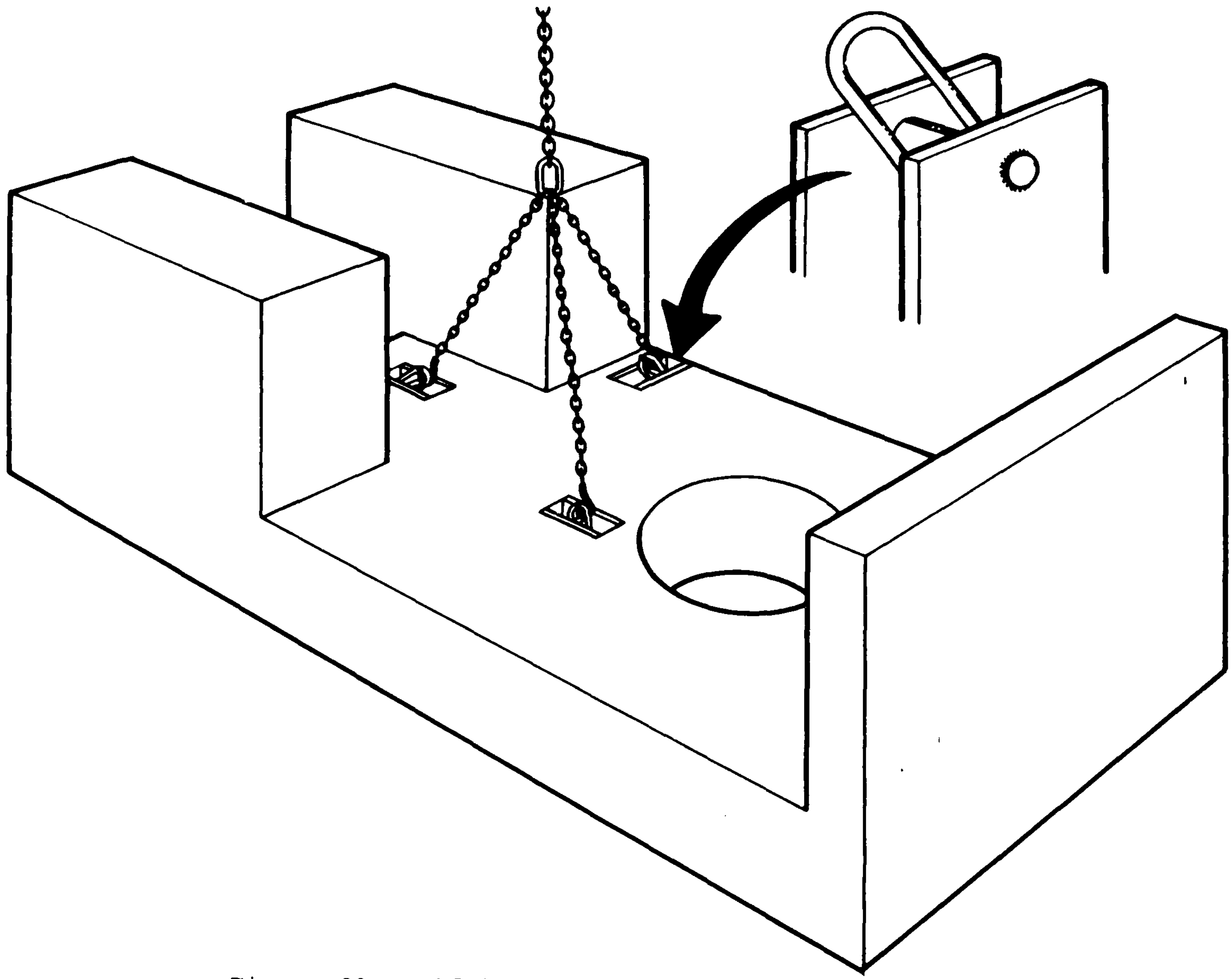


Figure 39. Lifting provisions - sling point detail.

4.6 Guide Roll System

Two sets of rolls serve to define the path the hose takes from the reel to the ground. A significant amount of design effort was expended to create the simplest hose path possible.

The hose was treated as a flat belt, rather than as a round tube. When properly evacuated, the hose simulates a belt nicely. Having a belt limits the number of stable paths that can be developed and creates other potential instabilities, such as the tendency of a belt to develop differential tension across its width and "walk" off pulleys.

The path developed for use consists of three turns across the width of the hose and one 90-deg twist. This configuration is stable, and does not develop differential tension between belt edges.

As stored on the reel, the hose is on edge. The first turn and the 90-deg twist that places the belt parallel to the ground is controlled by the index roll set. The second of these two rolls also controls the turn which points the hose down toward the ground. The pinch roll set then guides the hose down along the side of the truck and becomes the starting point for the final 90-deg turn to lay the hose on the ground. The path which the hose takes is shown conceptually in Figure 28.

The construction of the index roll assembly is shown in Figure 40. This roll group is required to move up and down to remove or load a hose into each of the four reel slots. A hydraulically-driven screw and nut assembly positions the index roll set. Moving the rolls is a manual operation with fiducial marks provided to indicate the proper stopping points.

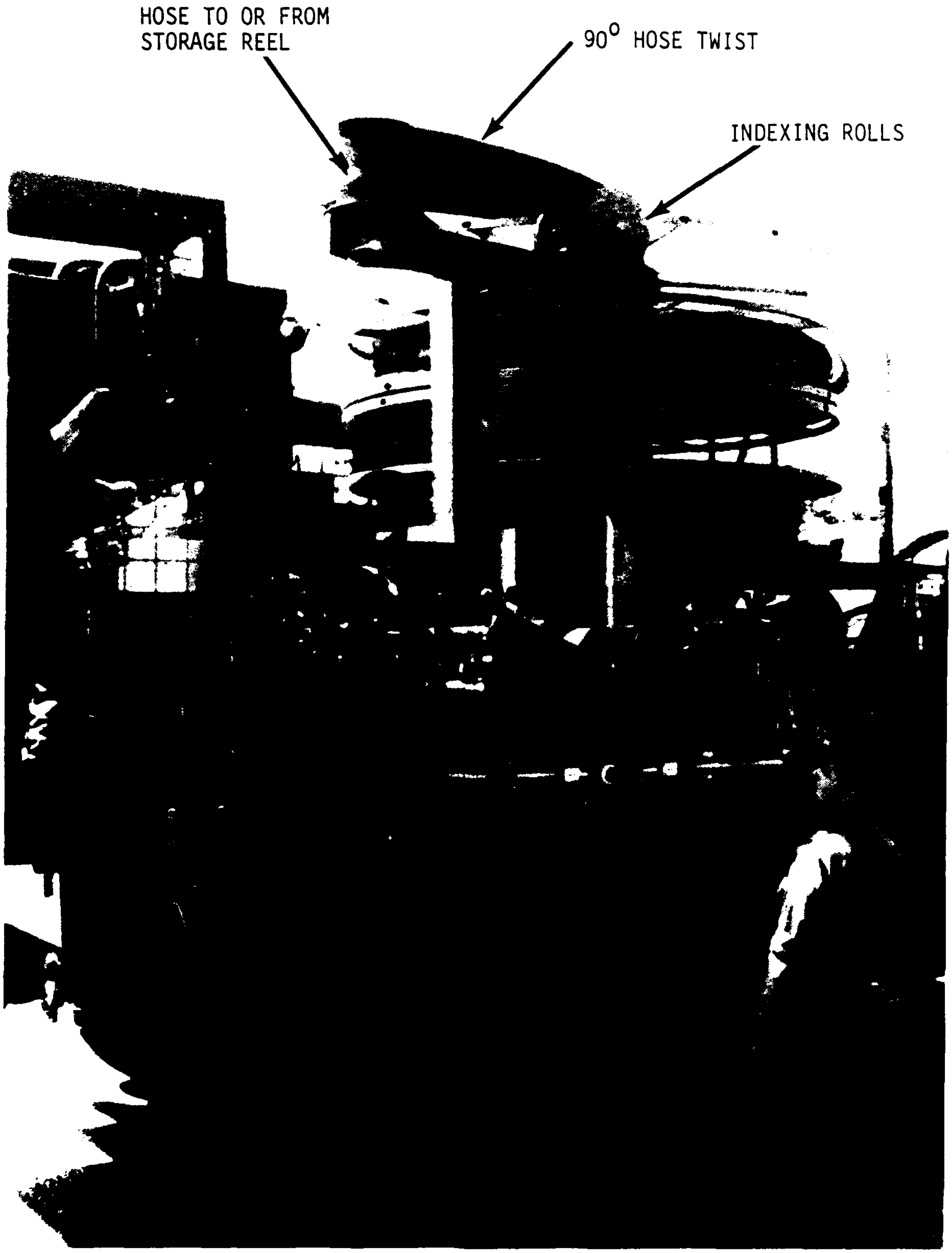


Figure 40. Index Rolls

The correct positioning of the index roll is critical to smooth operation and proper packing of the hose on the reel. The correct positions for deploy and recovery are different and are also dependent,to some degree, on the suppleness of the hose. Fortunately, the correct positioning of the index rolls is quickly learned in a few hours of operation. The hose must be threaded over the index rolls in such a manner that the hose twists 90% clockwise as viewed from the operator's station looking forward.

The pinch roll assembly (shown in Figure 41) consists of a pair of rubber surfaced rollers through which the hoseline passes during deployment or recovery. The rear roller is driven via a drive chain by a Char-Lyn Model 104-1061-005 hydraulic gear motor. The forward roller is an idler that is spring loaded to provide the desired pinching force on the hoseline. During deployment, the pinch rolls pull on the hoseline to take up slack as the hoseline is unreeled, and lay the hoseline on the ground. During pick up, the hoseline is dragged through the rollers by the reel assembly and the pinch rolls are back driven to tension the hoseline.

A tripping mechanism is designed into the pinch roll assembly to allow the pinch rolls to release and pivot upward (as shown in Figure 42 to permit the rigid adapter fittings at the end of the hose to pass through. The release can be activiated manually, using the release levers provided, or automatically when the adapter strikes the dancer roller located directly below the pinch rolls.

The dancer roller is attached to the end of a spring - loaded linear potentiometer that serves to sense the shape of the hoseline loop between the pinch rolls and the ground. If the rate at which the hose is unreeled is too slow for the vehicle speed, the hose is pulled taught against the dancer

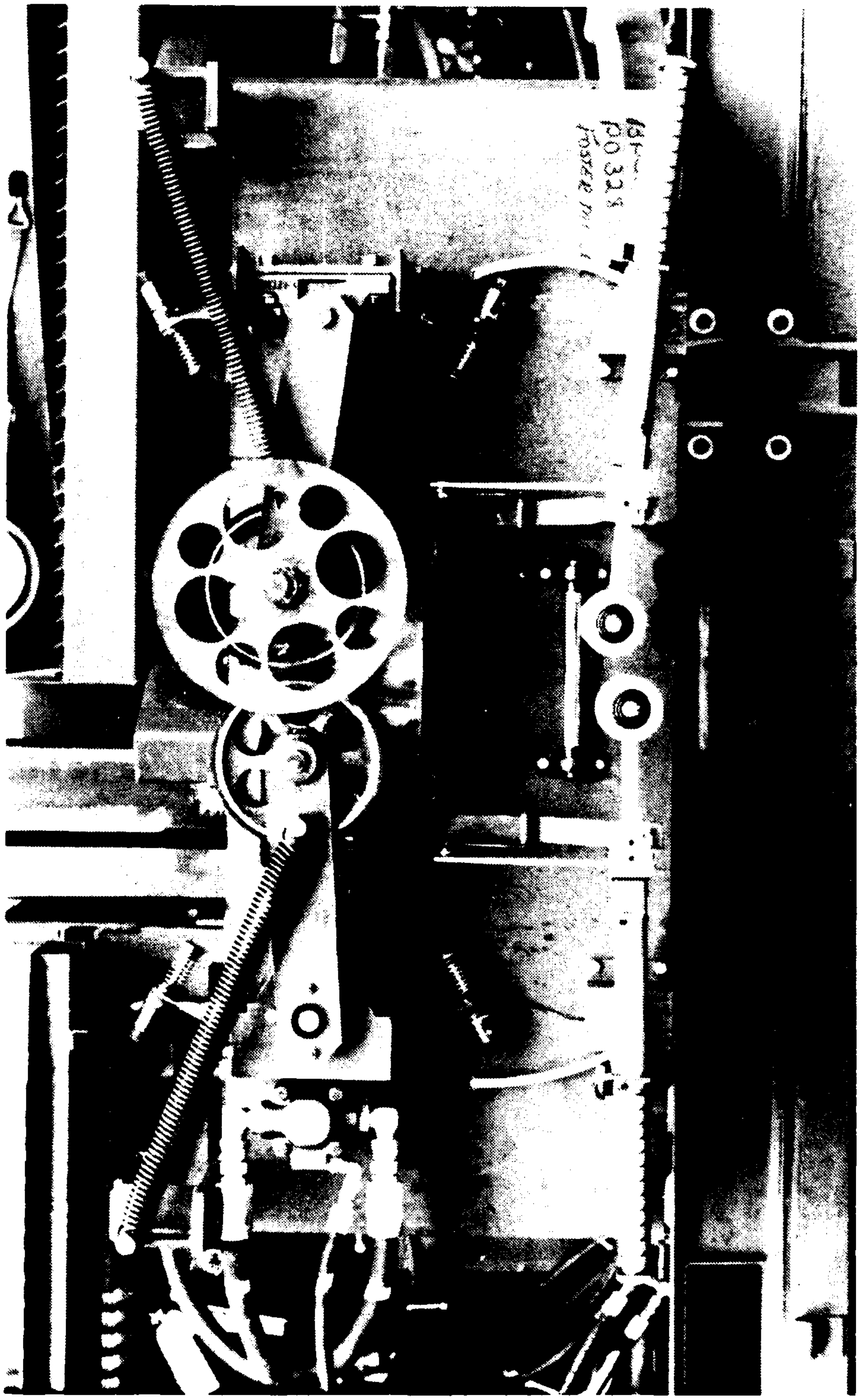


Figure 41. Pinch roll assembly

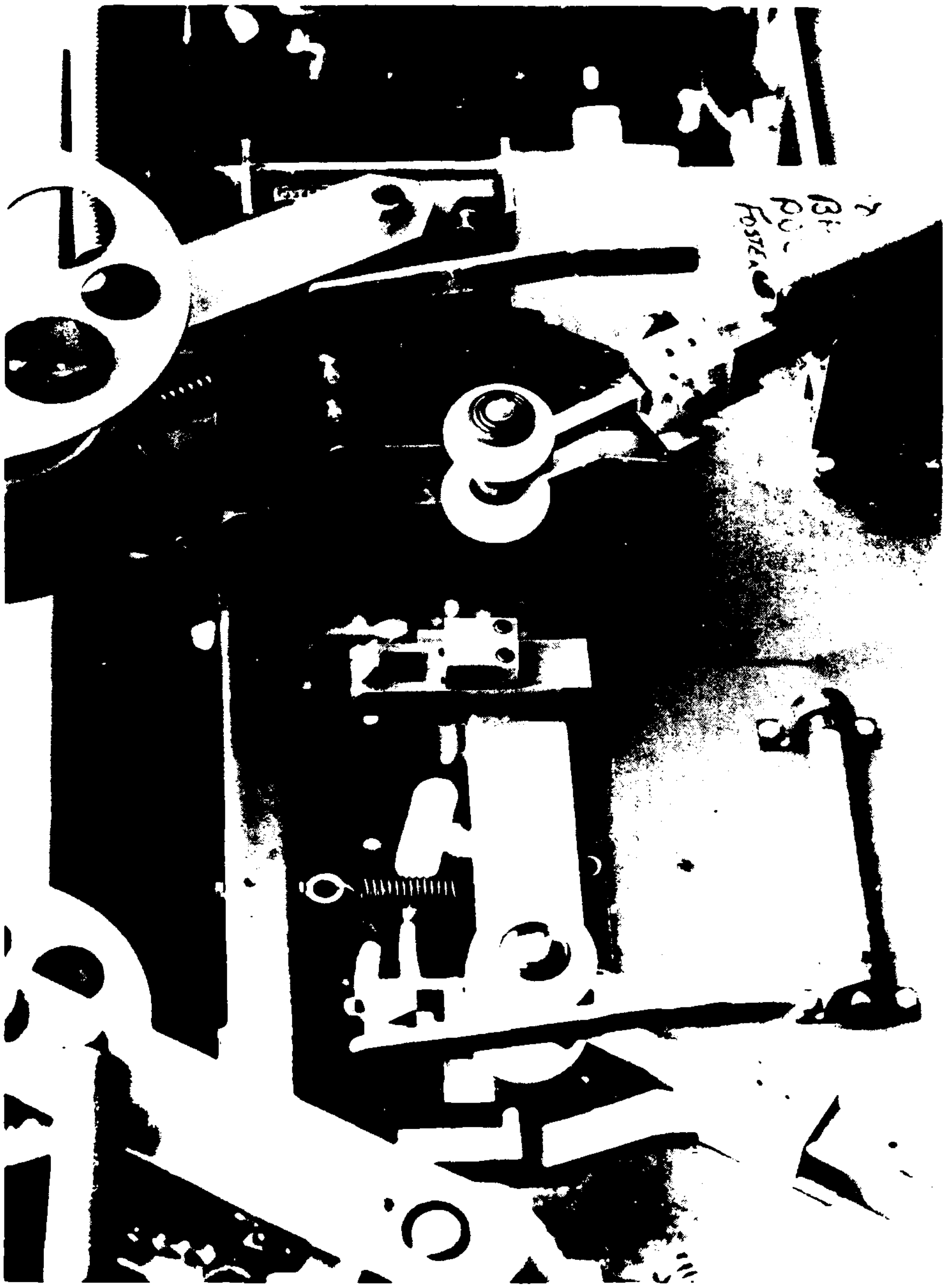


Figure 42. Pinch roll released.

roller stroking the linear potentiometer. This sends a command to the turntable drive system to increase the turntable reel speed. Conversely, if hose is unreeled too rapidly for the vehicle speed, the hose will go slack, the potentiometer will be fully extended, the pump will be commanded to zero stroke and the turntable will be dynamically braked.

4.7 The Hydraulic System

All of the functions of the HRA are hydraulically actuated. This power form is easily modulated to provide the wide range of speed and torque needed by the various components.

There are two powered functions used to actually lay or recover a hose. They are the reel drive and the pinch roll drive. The variable speed requirement of the reel drive and its need to respond to the truck's travel through a servo system suggested a hydrostatic drive for this component. A variable volume pump equipped with electrical and manual controls for displacement is connected to a radial piston hydraulic motor in a closed loop. Either through the automatic deployment system or through manual input, this hydraulic drive controls the speed and direction of rotation of the reel.

While the reel is moving under the direction of the hydrostatic drive, a constant tension is maintained in the hose by the pinch roll drive. The pinch roll drive consists of a gerotor-type hydraulic motor driven by a constant volume gear pump. Relief valves installed between the pump and motor ensures that a constant but limited pressure is supplied to the motor for torque control.

The amount of hoseline tension during recovery can be adjusted by means of a pressure relief valve. Test experience indicated that a setting of about 500 psig is correct. The hydraulic supply pressure to the pinch roll motor during deployment is set at about 1500 psi. Also, to increase the speed of the pinch rolls during deployment, the oil flow rate is increased by supplementing the flow from cam shaft-drive pump with oil from the main pump. This is accomplished automatically via a solenoid valve whenever the deploy mode is selected whether in automatic or manual control.

This tension serves two purposes. In picking up a hose, it ensures a good packing density on the reel. In laying a hose, it pulls the hose away from the reel and gets it off the truck.

Besides the two deployment functions, there are two ancillary hydraulic functions. One is used to raise the index roll assembly to reach the four reel slots. This function consists of a small hand-operated pilot valve which controls a larger valve to deliver oil from the pinch roll pump to the gear type hydraulic motor raising the index rolls. The second ancillary function is a circuit normally plugged off that allows the oil from the pinch roll pump to be taken off the HRA for remote use. This circuit has no current purpose in the operational scenario, but was provided for the convenience of future users at the request of MERADCOM personnel.

The hydraulic system in general is state of the art and is expected to be highly reliable. Filtration to the 3μ level is provided on the charge pump circuit feeding the hydrostatic drive, and 10μ filtration is provided on the constant volume pinch roll pump. A large hydraulic oil cooler is provided in the engine enclosure. The cooler is positioned in the engine cooling air flow so that it will warm the oil during low temperature operation. The recommended hydraulic fluid is mineral-base oil with antiwear additives. An annotated copy of the hydraulic circuit is shown in Figure 43 with the purpose of the components identified.

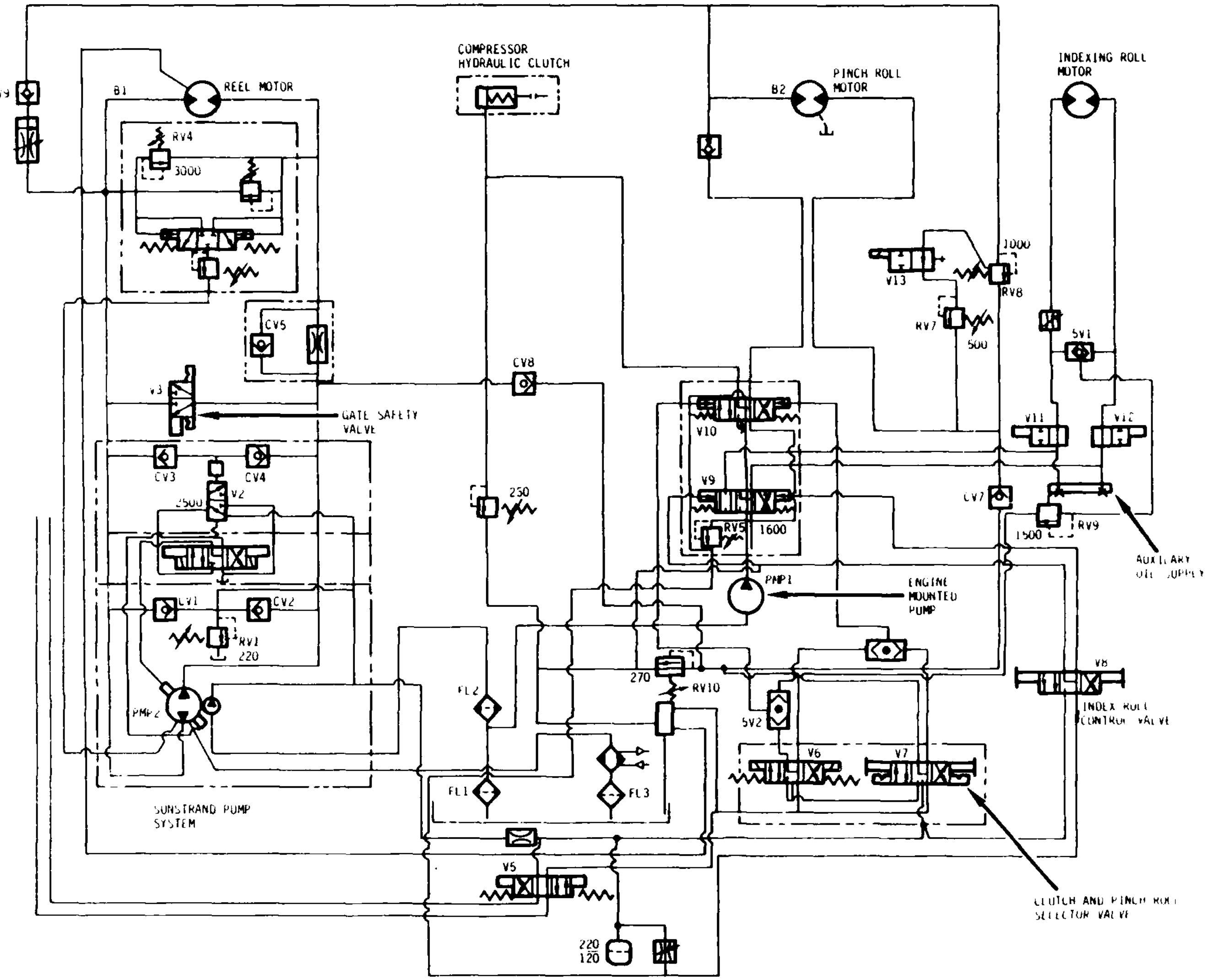


Figure 43. Annotated copy of hydraulic circuit.

4.8 Operator's Station and Automatic Deployment System

Three separate control systems are provided to pick up or lay hose within the Hoseline Reel Assembly. Although complete redundancy is not provided at all component levels, the control loops are independent, in that with virtually any control component failure another control loop exists which will enable mission completion. Examples of this independence will be demonstrated later.

The three control loops are an automatic control system, a manual control loop using electric controls, and a manual control loop using nonelectrical components. Their priority of use is as indicated: automatic, electrical manual, then mechanical manual. The mechanical manual system should be used for deployment only in extreme emergencies. The sensitivity of the feedback process decreases with each succeeding control loop.

The block diagram of the control options is shown in Figure 44. The main control switch is the key to control loop selection. In the positions *DEPLOY (DEP)*, or *PICK*, the automatic deployment system is in use. In the *MANUAL (MAN)* position the electric joystick is available for use. The manual hydraulic reel controller is available with the mode switch in Automatic or Manual.

The automatic control system is an electrical feedback circuit using the hose position off the side of the truck as the feedback parameter to adjust reel speed. The concept is shown in Figure 45.

During deployment, a tightening hose loop causes the reel to speed up by depressing the deploy sensor (R1). During recovery of a hose, shown in the second picture of Figure 45, a slackened loop permits the sensor (R1) to fully extend causing the reel to slow down. Owing to the inertia of the reel system, reverse

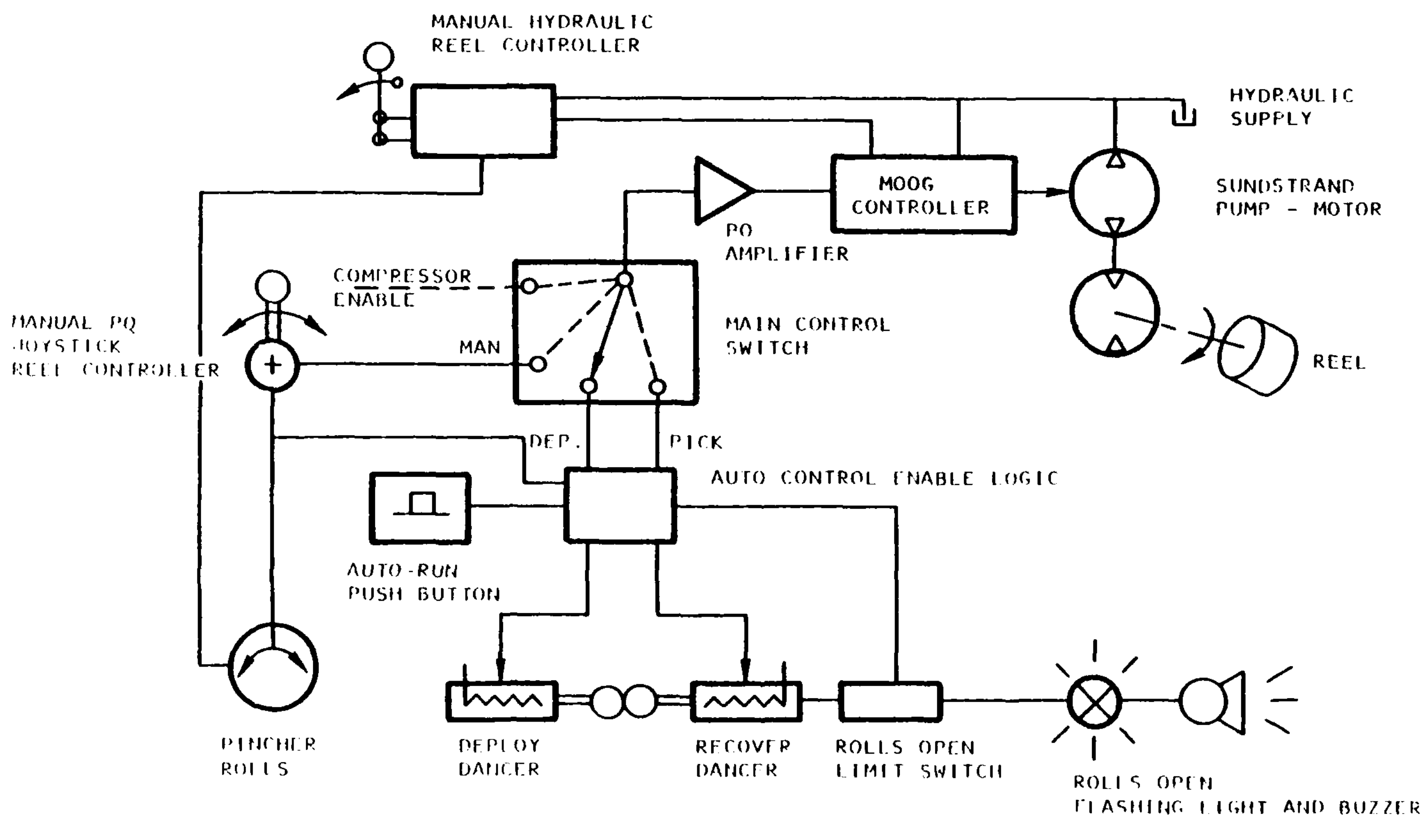


Figure 44. Reel drive control block diagram.

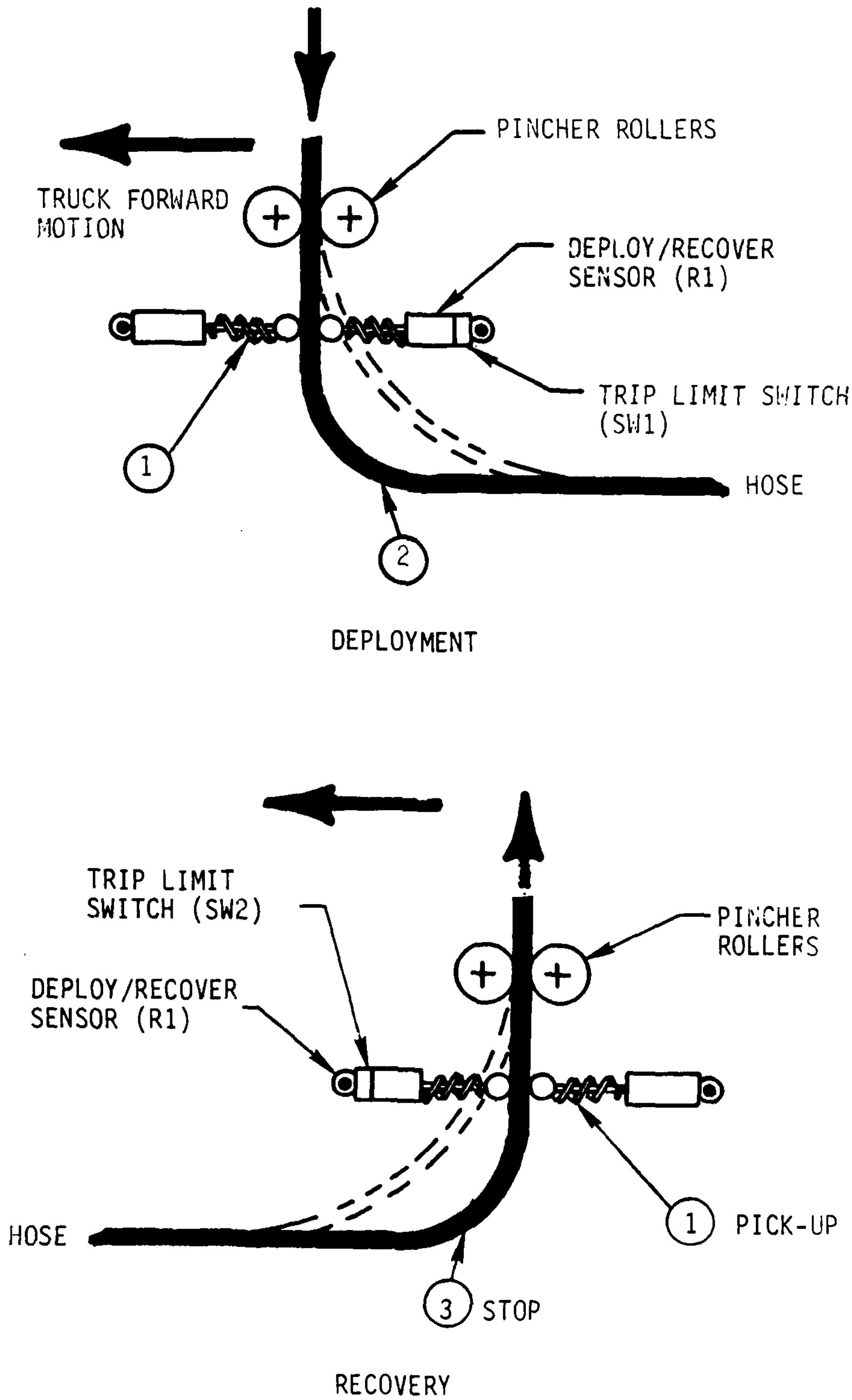


Figure 45. Automatic Deployment/Recovery concept.

direction signals are not transmitted through the electrical system to the hydraulic drive. The direction of rotation of the reel is selected by the main control switch; speed is regulated by the feedback control circuit.

Interlocks are provided with the automatic deployment system to ensure that the pinch rolls are properly engaged prior to initiation of control and throughout the control period. The engine throttle is electrically interlocked through the main control switch as well. Automatic control is initiated by a *START* button after control mode selection. Automatic control is terminated by control mode change (main control switch movement) or by a *STOP* button. It is, of course, terminated by the *EMERGENCY STOP* button as well, but this is an abnormal stop which requires special procedures to restart.

The layout of the operator's control panel is shown in Figures 46 and 47. Figure 46 shows the controls for all three control loops. These will be described presently. The left hand area of Figure 46 is concerned with the mode selection and automatic deployment system. It is isolated in Figure 47. To operate the automatic deployment system, the operator selects *DEPLOY* or *PICKUP* on the main switch. He checks to see that the amber *ROLLS OPEN* light is off, then presses the button marked *START AUTO*. The engine speeds up and the dancer roll becomes active to drive the reel in response to the truck's movement. To shutdown the automatic system, the *STOP* button can be depressed or the mode switch can be moved.

To activate either of the two manual control loops, the main control switch in Figure 47 is moved to *MANUAL*. When this is done, the electric joystick in the middle of the console of Figure 46 is active and available for use. It is interlocked

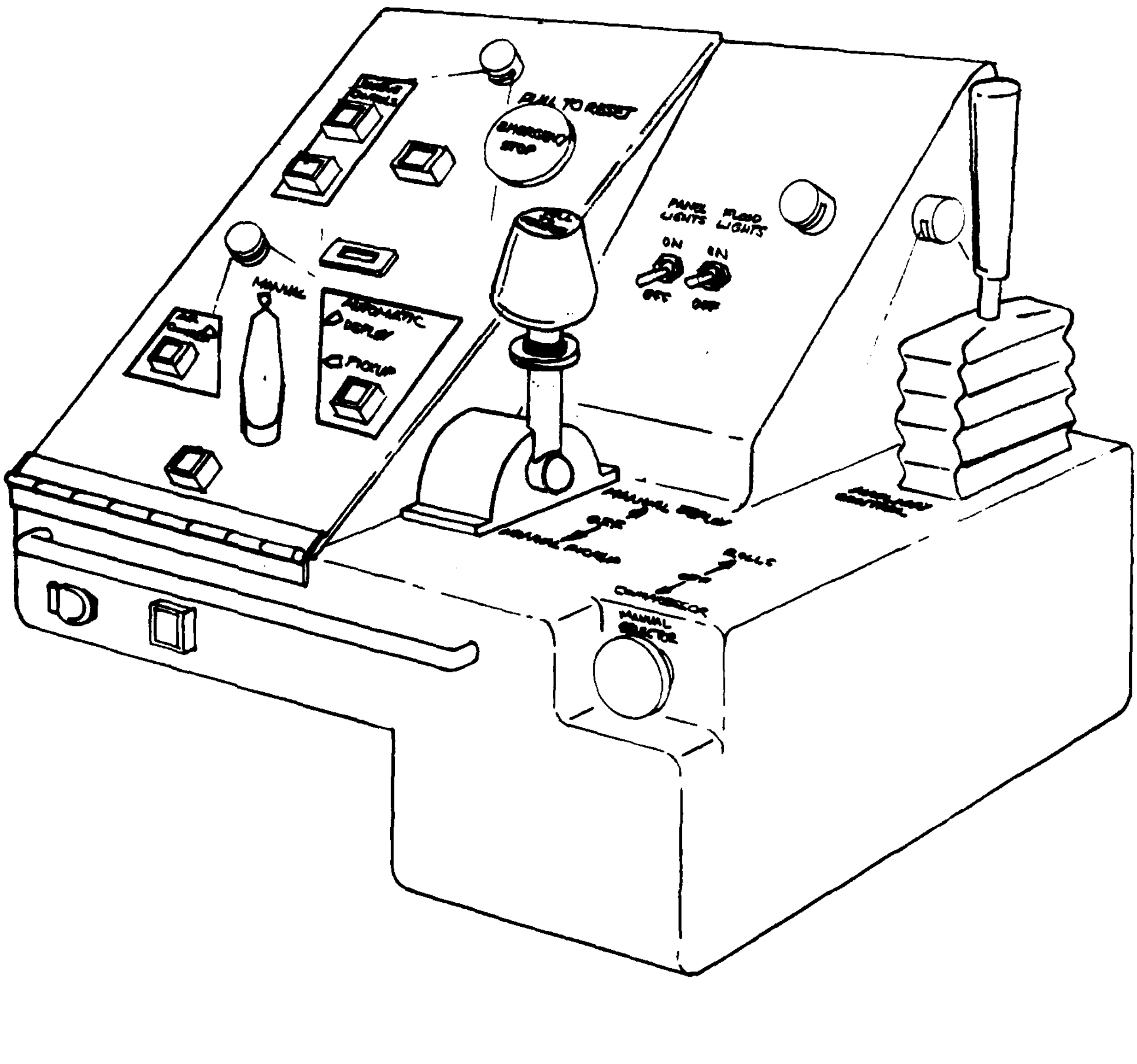


Figure 46. Operator's control panel.

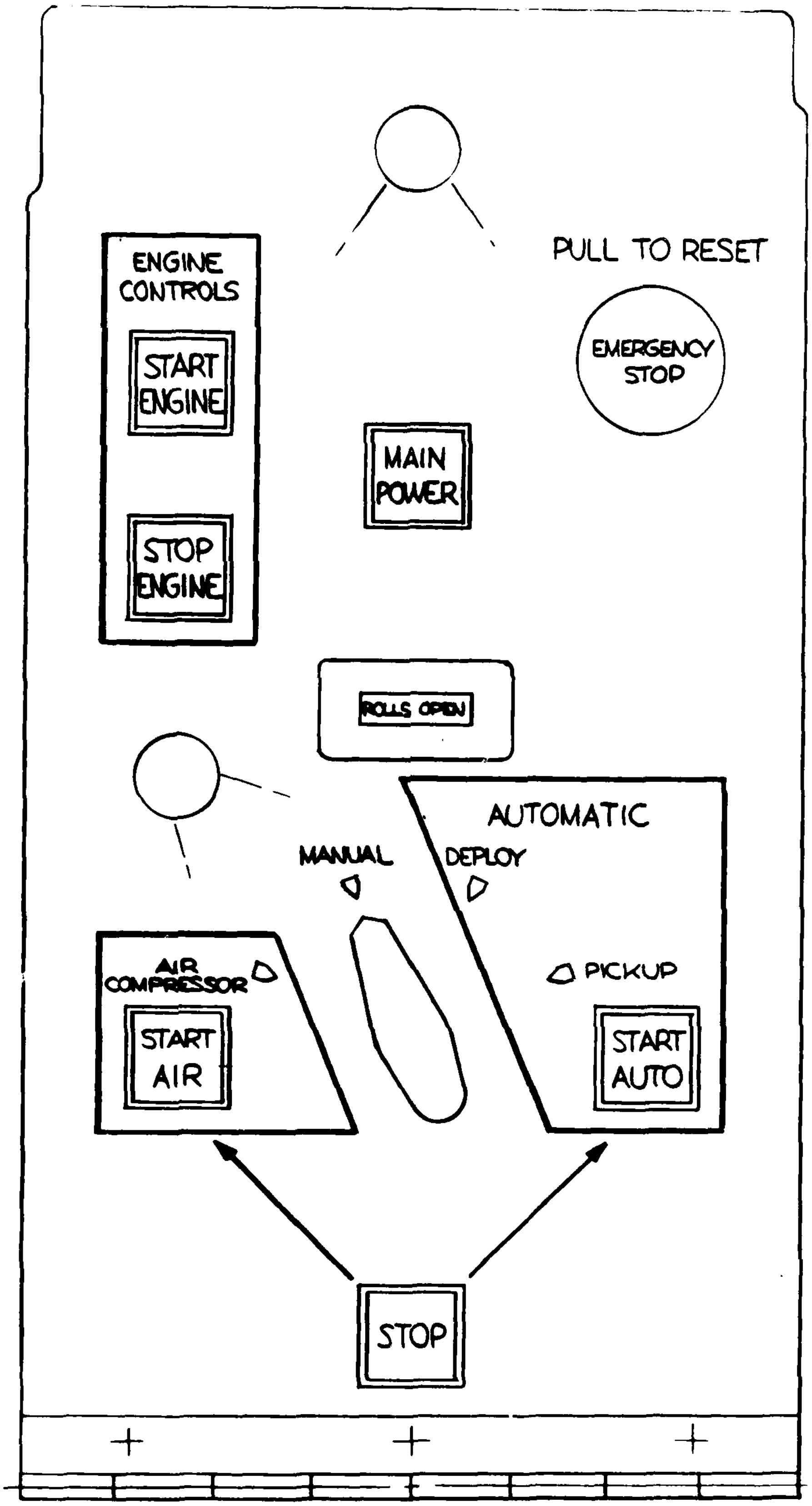


Figure 47. Mode selection, automatic deployment system.

electrically with the pinch roll drive to ensure the pinch rolls operate when it does.

With the mode selector switch in either *AUTOMATIC* or *MANUAL*, the mechanical joystick on the far right-hand side of the panel is available for use. The lever provides on-off or "bang-bang" control of the Sunstrand variable volume pump by means of a hydro-mechanical link. When the joystick is displaced off its center, neutral position, a small hydraulic actuator strokes the pump controller a fixed amount. The reel control joystick is not interlocked with the pinch rolls. A separate push-pull selector knob is used to manually activate either the pinch rolls or the air compressor. To deploy hose in the mechanical manual mode, the selector knob must be pushed in to the "Rolls" position to activate the pinch rolls before moving the joystick. Since a higher pinch roll drive hydraulic pressure is used in deploy than in pick up, the supply pressure must be manually set to the higher pressure for mechanical manual operations. This is accomplished by removing the vent line from the vented relief valve (RV8) and installing a 1/4 in. NPT plug in the vent port. The vent line must be capped to avoid contamination. For recovery operation, the plug should be removed and the vent line reconnected.

Because the mechanical joystick is a bang-bang control, precise control of the reel speed is very difficult; hence, hose deployment in this control mode should be attempted only in extreme emergencies.

The intent of the three-control concept was to make the hose deployment as easy as possible for the operator, consonant with mission accomplishment. This has been achieved by the independent control loops that can ensure mission completion in spite of major control component failure.

Just one example will emphasize this point. Consider that the HRA battery is dead and the engine alternator is malfunctioning. Once the engine is started, hose can be recovered or deployed. The throttle must be set manually under the enclosure cover, but then the system can go. The electrohydraulic controller on the Sunstrand pump is dead, but the direct hydromechanical link to the pump is available. This flexibility to accomplish the mission is extremely important to the soldier on the line.

4.9 Truck Tiedown System

The HRA is mounted on a cargo vehicle for use. The concept of the interface between vehicle and HRA was to avoid rework of the vehicle so that its primary capability to carry general cargo was not sacrificed. Insofar as possible, the interface was not to create a dedicated vehicle.

Through MERADCOM's knowledge of the Army inventory and a growing understanding of the needs of the concept, a decision to marry the HRA to the M813A2 5-ton, 6 × 6 cargo truck, equipped with the drop-side cargo bed, was made early in the concept stage. A truck was delivered by MERADCOM to Foster-Miller to facilitate design of the Deployment/Recovery Device-Truck interface. Based on the decision to target the M813A2, design decisions were made which simplified the developing hardware. Principally, the task of stowing the pinch rolls was eased.

The tiedown system is free of any need to modify the M813A2 vehicle, beyond removing the dropsides and tailgate and spare tire at the motor pool prior to installing the HRA. As the HRA is installed, the tiedown clamps serve to position the HRA properly on the truck bed. Tightening a series of 12 bolts securing 6 clamps then locks the HRA securely in place on the bed.

The tiedown system is deceptively simple. It is an integrated design dedicated to this one truck bed. The clamps are uniquely positioned over the lateral reinforcing beams under the cargo floor. This is necessary to resist the concentrated clamp forces and to distribute the operating forces into the bed without localized distortion. A tiedown clamp is shown in Figure 48.

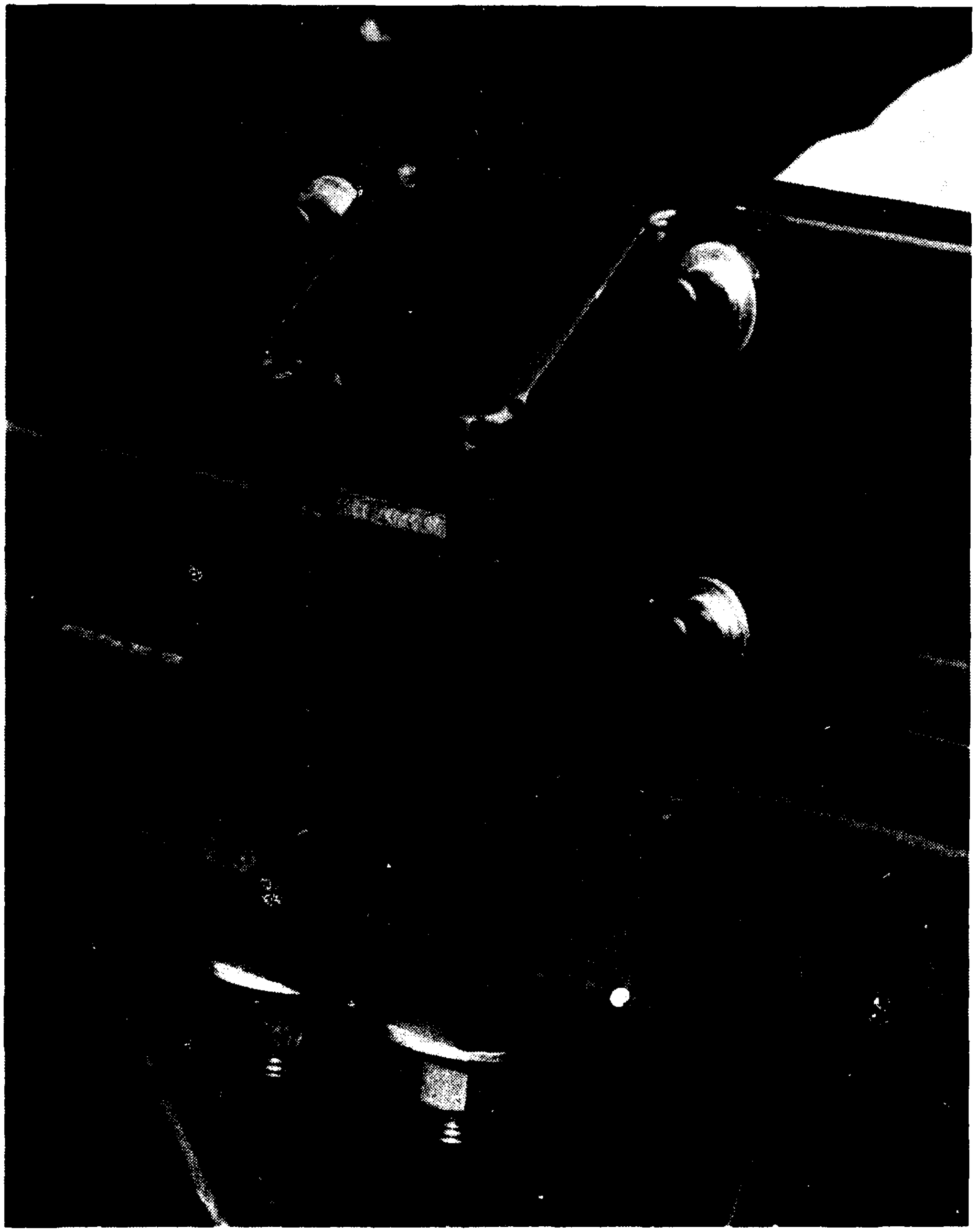


Figure 48. Tiedown clamp.

AD-A134 374 DESIGN AND DEVELOPMENT OF MILITARY PETROLEUM HOSELINE SYSTEM(U) FOSTER-MILLER INC WALTHAM MA M S CETINER ET AL. AUG 83 MER0216-FM-8055-5 2/2

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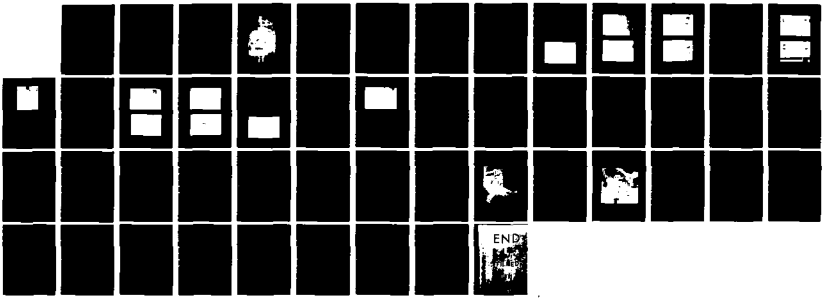

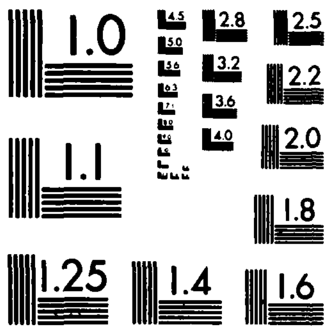

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5. CHARACTERISTICS OF THE HOSELINE REEL ASSEMBLY

The final configuration of the Hoseline Reel Assembly is shown in Figure 49. Its summary statistics are given below:

a. *Dimensional Data* - Hoseline Reel Assembly

Length: 193 in.

Width: 83 in. stored, 106¼ in. operational condition

Height: 82 in. with no reels, 91½ in. with two reels

Hoseline Reel Assembly Weight w/o Reels: 10,870 lb

Loaded Reel Weight: 3,550 lb/1,000 ft hose

Hose Storage Capacity: 2000 ft of 6-in. petroleum hose

Storage and Shipping Container: 20-ft Milvan or ISO container

b. *Operating Dimensions on M813A2 Dropside Truck* (including the truck) -

Overall length: 326 in. (without winch)

Width: 97-1/2 in. (road travel condition)

Height: 138 in.

Total Weight: 1 reel; 500 ft hose, 32,540 lb
2 reels; 2,000 ft hose, 37,620 lb

c. *Operating Conditions* -

Maximum truck speed: 5 mi/hr

Side slope capability: 15 deg

d. *Major Components* -

Engine: GMC Detroit Diesel 353

Fuel Capacity: 28 gal No. 2 diesel fuel

Hydraulic System:	1 Sunstrand Pump
	1 Vickers Pump
	1 Sunstrand Motor
	1 Eaton Char-Lynn Motor
	1 Electric Solenoid Valve
	1 Pilot-operated Valve
	1 Hydraulic Oil Cooler
	4 Relief Valves

Hydraulic tank capacity: 30 gal

Electrical system: 24V, 2 batteries, 12V, MS35000

Hose purging system:	70 ft^3/min Quincy Air Compressor
	GL-1 Penberthy Ejector
Hose:	500-ft length of 6-in. petroleum hose manufactured by Durodyne, Inc.
Hose Coupling:	Victaulic-type seal in custom ring clamp seal and couplings per MIL-C-10387C.

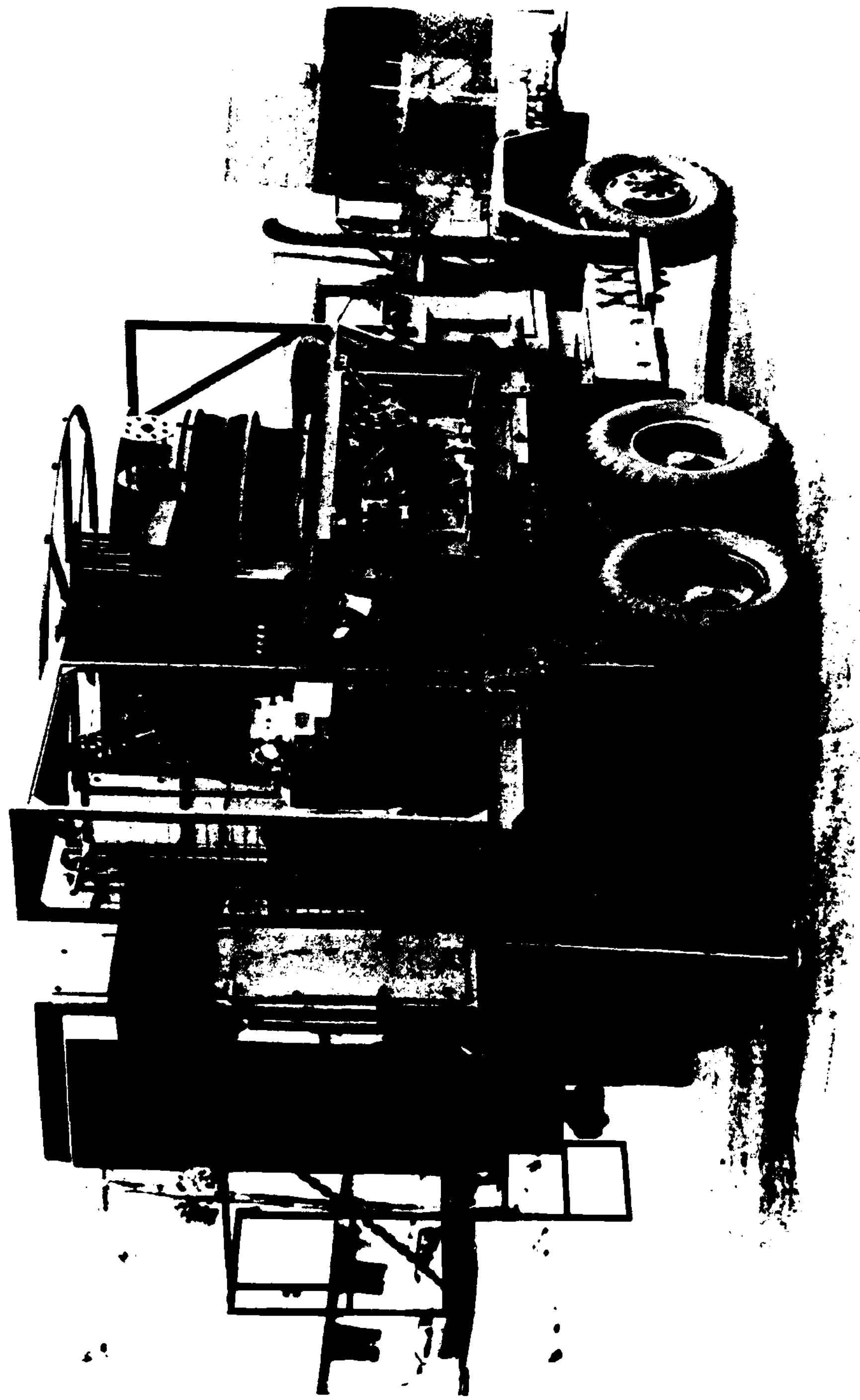


Figure 49. Final PHS configuration.

6.0 FABRICATION, ASSEMBLY AND TEST OF THE HRA

The HRA was assembled at Foster-Miller's Waltham, MA. facility during the spring of 1982. Major subsystems and components such as the base frame weldment, the engine enclosure, index roll assembly, and reels were manufactured by local subcontractors in conformance with Foster-Miller's engineering drawings. Five (5) 500 ft hoseline assemblies were received from Durodyne in mid April and spooled onto three dual reels at Foster-Miller.

Integration and checkout of the Hoseline Reel Assembly continued through the month of April and the controls and safety related features were demonstrated to MERADCOM personnel on 28 April 1982. System integration and debugging continued in May and the unit was shipped to Aberdeen Proving Ground for DT-1 testing on 2 June 1982.

During this period, the hydraulic system was modified to increase the flow of hydraulic oil to the pinch roll drive motor when deploying hose. Because the pump for the pinch rolls is driven off the cam shaft of the GM3-53 diesel, the available horsepower for driving a pump is limited to 10 horsepower. Consequently, a larger pump could not be installed to provide the increased flow at 1500 psi. To minimize the impact on the overall system, a system for diverting some flow from the main (turntable) pump was designed and installed. During deployment, approximately 6 gpm of oil from the main pump is diverted via a vented relief valve and solenoid control valve to supplement oil from the cam shaft driven pinch roll pump. The additional flow (a total of about 13 gpm at 1500 psi) ensures that the pinch rolls will drive fast enough to avoid excessive slack in the hoseline as it comes off the reel and passes over the index rolls.

The only other significant modification during this time period was the addition of a spring loaded bail to the vertical axis index roll. The hose has a tendency to fall off the index roller if slack develops in the hose during deployment. The bail proved to be very helpful and made the system more forgiving of variations in hose thickness and stiffness (e.g. the splices) and hose tension. The design if the bail was improved upon during DT-1 as described in Section 8.

The performance of the reel control system was initially very erratic. This proved to be due in large part to air entrapped in the hydraulic system and the low setting of the cross-over relief valves. The cross-over relief valves were set at 3000 psi and the air was ultimately purged from the system resulting in greatly improved response particularly in dynamic braking.

A test and demonstration of the HRA was completed at Foster-Miller, Waltham, MA. facility prior to shipping the unit to Aberbeen Proving Ground. The results are documented in Foster-Miller Report No. MER 0216-FM-8055-1.

7. TRAINING COURSE

An Operating and Maintenance Training Course for government personnel was conducted by Foster-Miller at their Waltham facility. The course was conducted in accordance with the approved Training Course Outline and Training Course Lesson Guide, prepared by Foster-Miller, and was conducted during the period 10 May through 21 May 19-3. The course was attended by the following persons:

NAME	ORGANIZATION
Emil Czul	DRDME-GS MERADCOM, Ft. Belvoir, VA
Batts, L.	Ft. Lee, VA
McClung, Gary L., SFC	USAARENBD, Ft. Knox
Brown, Ernest P., CPT	USAARENBD, Ft. Knox
Bowers, William A., SGT	USAOC&S, Aberdeen Proving Ground
Stuart, Theodore L, SSG	USAOC&S, Aberdeen
Vaughan, Weldon B.	USATSARCOM, Ft. Hood, TX
Dust, Frank M.	USALAO-TSARCOM Box 2412, Ft. Riley, KS 66442
Ayala, Jose	USAQMCEN, Ft. Lee DTD Supp/Serv. (project NCO)
Morrison, Harold	MTD, APG, MD

The Training Course Outline is presented in Appendix B.

8. CONTRACTOR TECHNICAL SUPPORT TO DT-1/OT-1 TESTING

Foster-Miller provided technical support to the DT-1 testing at Aberdeen Proving Ground (APG) and to the OT-1 testing at Fort Pickett. The problems addressed and the resulting hardware changes are discussed in the following paragraphs.

During initial start-up at APG, it was determined that the electric joystick controller was malfunctioning, commanding the turntable to rotate at nearly full speed with no manual displacement of the joystick. The problem was traced to the fact that the set screw that secured the drive gear and cam to the P-Q joystick potentiometer shaft was loose and the potentiometer was effectively stuck in a nearly full stroke position. The gear and cam were properly aligned on the potentiometer shaft and the set screws retightened. No further problems with the joystick were encountered. A minor modification consisting of drilling three holes in the bottom of the control panel was made to facilitate removal of the joystick controller.

Deploy/recover operations at APG indicated that some hardware modifications were needed to improve system performance, particularly when deploying hose. The hose, when collapsed, is slightly wider than expected (10 in. versus 9 5/8 in.) and consequently does not reel on and off the reel as smoothly as it should or wrap around the index roll as well as it should. The reel slots measured between 9.5 and 10.25 in. at the outer rim which resulted in excessive snagging of the hose and varying degrees of slack between the reel and the pinch rolls. It was also noted that the pinch rolls had a tendency to skid on the hose when it was wet.

To improve system performance, two of the reels were reworked to widen the slot width to 12 in. and the index rolls were modified to increase the diameter of the flanges from 11 to 13 in. and also increase the distance between flanges from 10.25 to 12 in. Pinch rolls having a softer, textured rubber surface were installed. The new covering is 30 durometer BUNA rubber with 3 circumferential grooves 1/4 in. wide by 1/8 in. deep cut into the surface. At this time, the pinch roll release handles were replaced also with heavier (3/8 in. versus 1/8 in.) handles These modifications are shown in Figures 50 through 52.

A modified bale that is compatible with the larger index rolls was installed with the index rolls to improve retention of the hose on the vertical axis index roll. The bale consists of two high molecular weight polypropelene rollers which contact the hose near the top and bottom of the flattened hose. The tension in the tensioning spring can be adjusted by means of a turnbuckle. (See Figure 52).

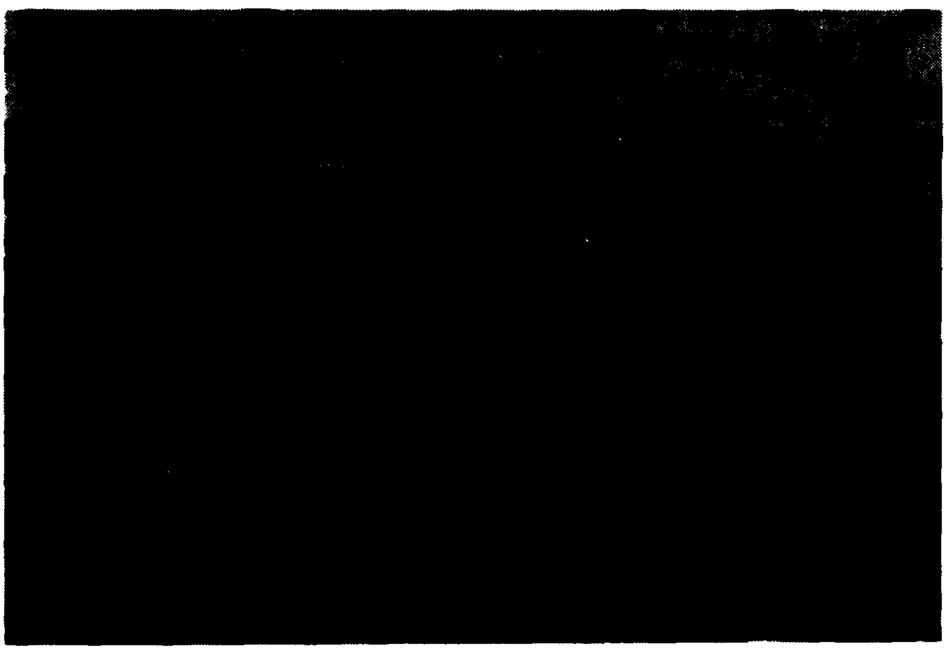


Figure 50. Reel modification for additional clearance.

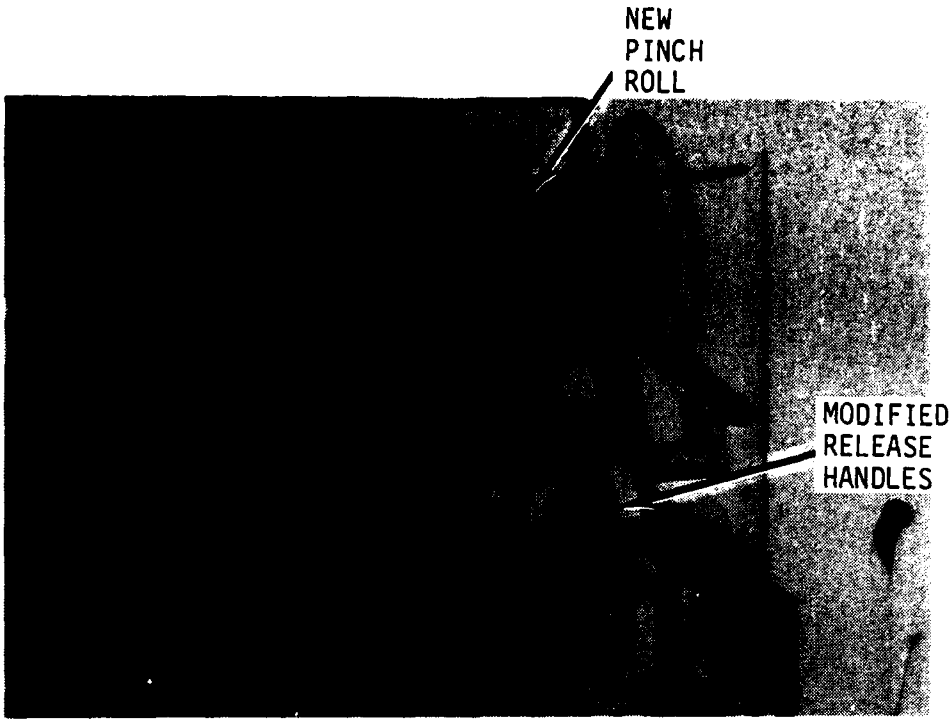


Figure 51. Pinch roll modification.

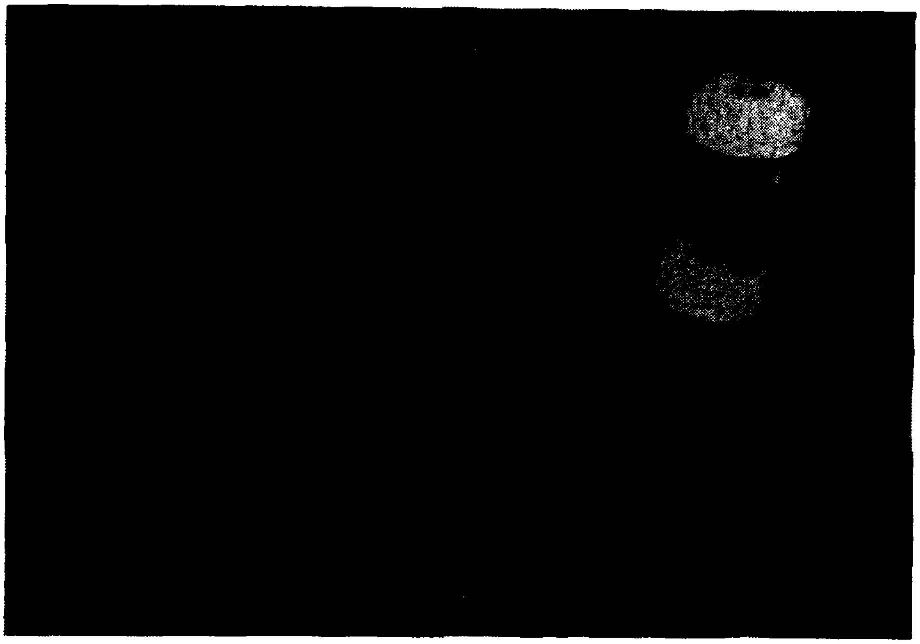


Figure 52. Index roll bale modification.

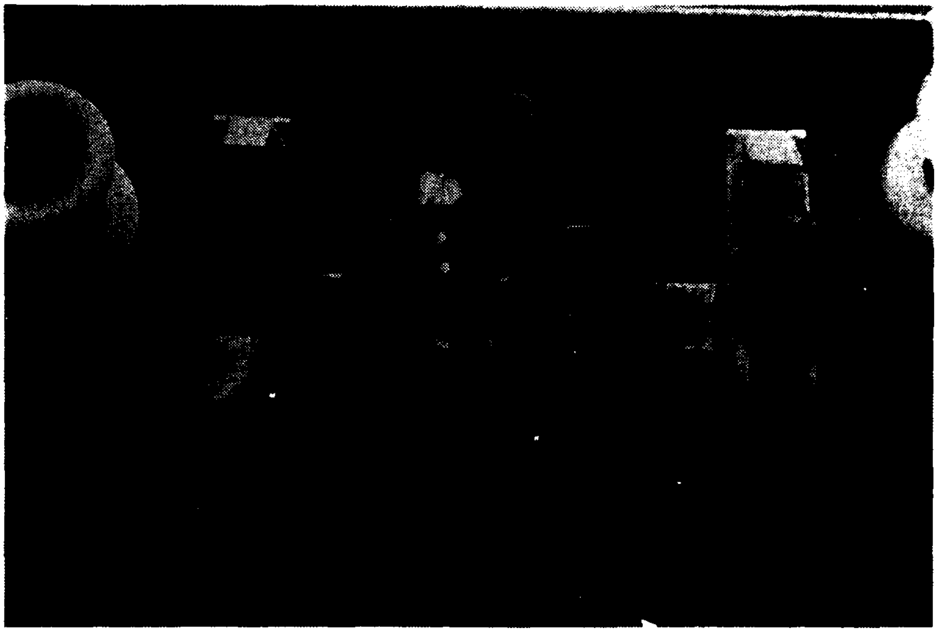
To provide additional guidance for the hose as it passed from the index roll through the pinch rolls, two hat-section-shaped guides were added to the pinch roll release bar as shown in Figure 53. These guides eliminated the problem of the hose riding in behind the pinch rolls and jamming.

With the above modifications, the system's performance was improved. However, recovery (or pick-up) operations continued to be smoother than deploy. When operating in the deploy mode (automatic or manual control), excessive slack was developing between the reel and pinch rolls during turntable braking. It had been noted that the charge pump pressure momentarily fell to zero during turntable braking. The charge pump provides pilot pressure for the control valve that controls the operation of the pinch rolls and the momentary loss of pilot pressure was causing the pinch rolls to stop. Thus, the pinch rolls were effectively clamping the hose at a point between the reel (which is still paying out hose) and the ground. This resulted in excessive slack between the reel and the vertical axis index roll.

To correct this problem, a small hydraulic accumulator was installed in the charge pump circuit to maintain charge pressure during turntable braking. The accumulator is rated for 2000 psi and is operating in the system at about 200 psi. With the simple modification, system performance during deploy operation was dramatically improved. The accumulation is shown in Figure 54.

The screw drive for positioning the index rolls performed erratically for a period of time. It was determined that a closed center spool had inadvertantly been installed in the manual pilot valve instead of the specified open center spool. The correct spool was installed and the problem was corrected.

The locking pawls and the mating slots in the reel hubs were reworked to add a positive rake to the pawls and add a



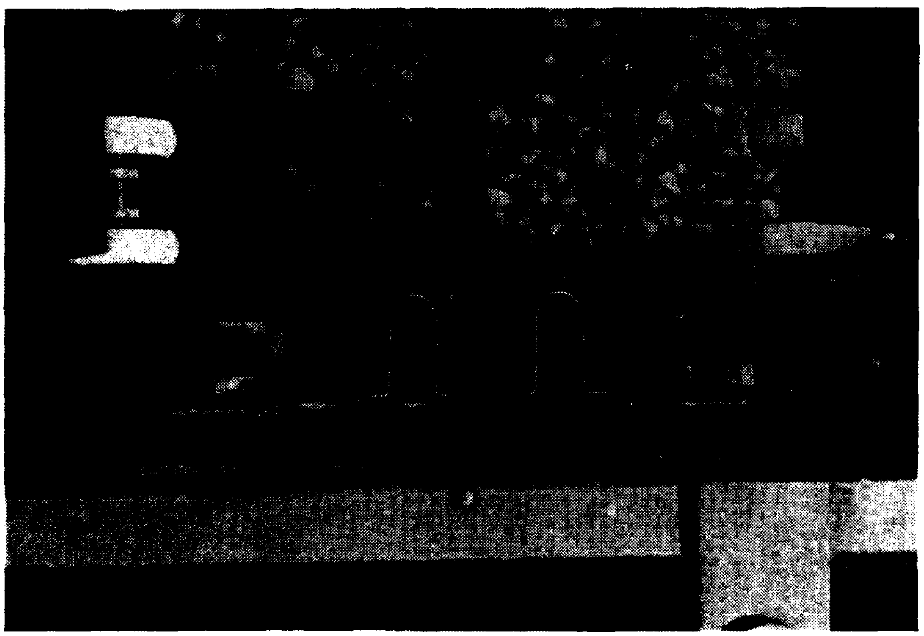


Figure 53. Pinch roll guide modification.

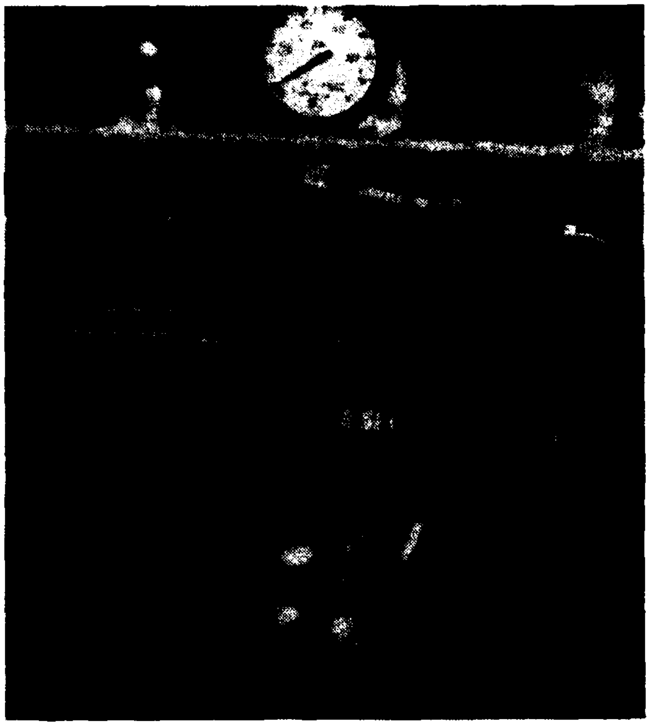


Figure 54. Accumulator installation.

chamfer to the mating surface of the reel slot to ensure proper locking between reels. The locking pawls in the turntable were also reworked to strengthen the tip of the pawls.

At the start of OT-1, the floodlights for night operation were modified to improve lighting in the area of the pinch rolls. The floodlight on the inboard, foward corner of the engine enclosure was removed and two portable, clamp-mounted lights were added. The selected light is a fog light type with a narrow, flat beam and worked out very well in OT-1.

The voice communication system appeared to be malfunctioning after a lost microphone was replaced by APG personnel. Upon further investigation, it was determined that the replacement microphone had an impedance of 30Ω instead of the required 160Ω resulting in a substantial loss of output. The correct microphone was installed, correcting the problem.

The HUSCO clutch that engages/disengages the air compressor failed and was replaced. Because the clutch had obviously overheated, the hydraulic syste was modified slightly to provide a continuous flow of hydraulic fluid through the clutch housing for cooling as shown in Figure 55. The clutch failure is attributed to initial start-up problems at Foster-Miller that were not recognized at the time.

Running the air compressor for extended periods of time in high ambient temperatures resulted in overheating of the diesel engine and, consequently, automatic shutdown of the engine. The problem is due to the restricted air flow through the engine enclosure. With the additional heat load of the air compressor, the air flow is inadequate. The expedient solution for the prototype HRA was to remove the front top and rear lower engine enclosure panels to improve cooling air flow. Sound measurements were taken with the panels removed with the following results:

a. At operator's station, system stationary, diesel at 1200 RPM — 86 dBA

b. At operator's station, diesel at 1200 RPM, deploying and recovering hose — 87 dBA

Heating protectors were provided and DT-1/OT-1 continued.

A number of displacement pigs were tried with the system for purging the hoseline of liquid (water was used in testing). Of the four (4) types of pigs shown in Figure 56, only the 12 in. long 6-1/2 in. diam urethane foam pig worked satisfactorily.

The four types of pigs are discussed in the following paragraphs:

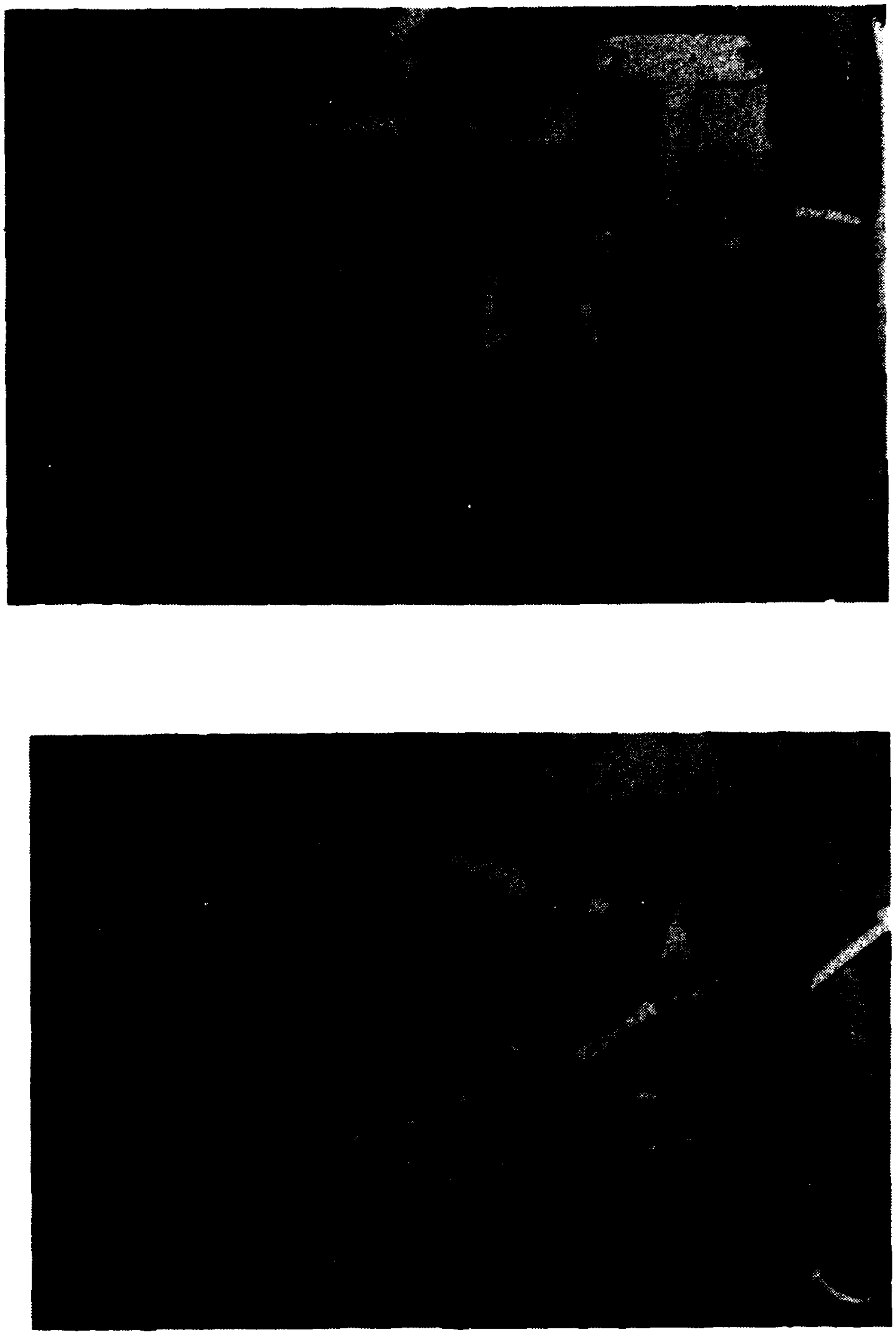
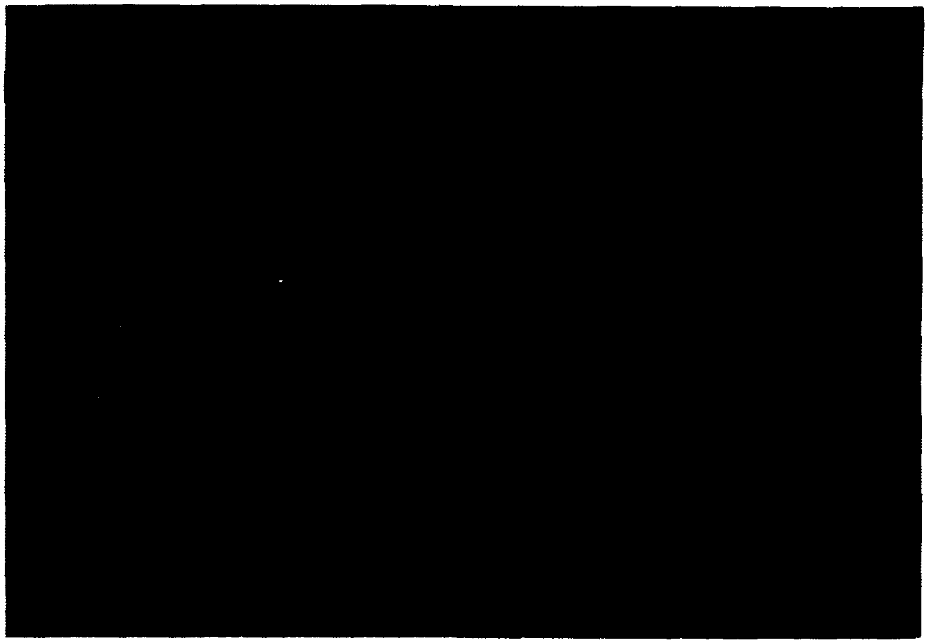


Figure 55. Clutch cooling modification.



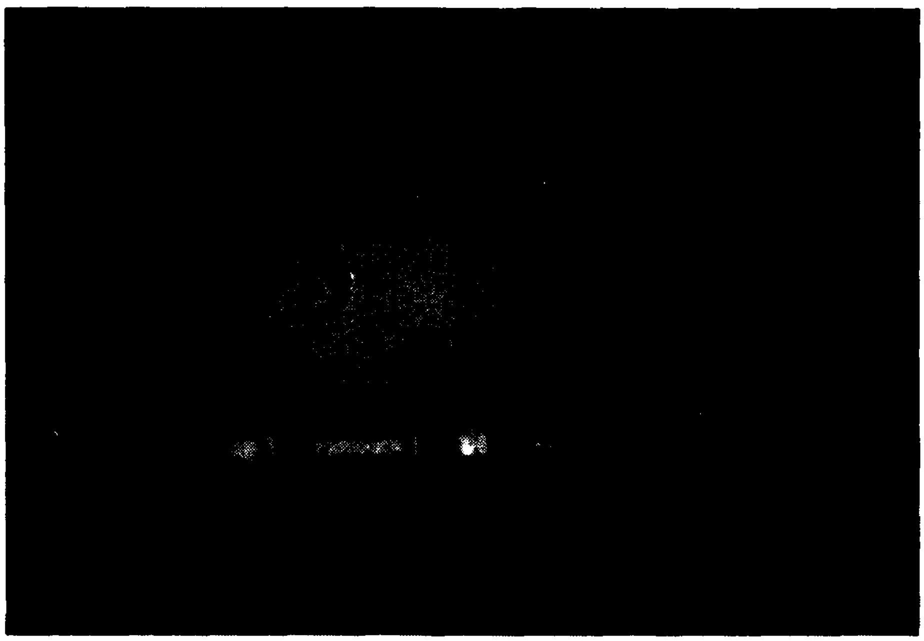


Figure 56. Displacement pigs.

a. Bullet-shaped urethane foam. The evacuation kit as received from Durodyne (Figure 57) contained bullet-shaped urethane foam pigs. A semi-rigid plastic disk was bonded to the base of the pigs. In use, the plastic disk had to be deformed to insert the pig into the hose adapter fitting. When compressed air was introduced behind the pig, the pig moved only a few inches and stopped. The semi-rigid disk apparently deformed and allowed the air to flow past the pig. The semi-rigid disk was removed and the pig tried again without success.

b. F.H. Maloney - Inflatable Sphere. A so-called "inflatable" rubber sphere was then purchased from F.H. Maloney Co. The ball proved to be virtually rigid and could not be manually inserted into the adapter fitting. These balls are widely used commerically but in rigid pipe-not in hose. They are "inflated" by pumping liquid into the hollow core.

Figure 57. Evacuation kit.

c. F.H. Maloney then provided a sample pig consisting of multiple rubber disks mounted to a common shaft as shown in Figure 56. While the concept appears reasonable, the disks are much too stiff and the pig could not be manually inserted into the adapter.

d. Pneumatically inflated ball - In an effort to determine if a pneumatically inflated sphere would work, a child's soccer ball was tried. The under inflated soccer ball worked very well indeed. The soccer ball was inflated to about 1.0 psi and had an outside diameter of 6.5 in. The use of a rugged (heavy walled) pneumatically inflated sphere may prove to be the preferred pig for the system as discussed in Section 9.

e. Urethane Foam Cylinders - Cylindrical urethane foam pigs were received from Durodyne to replace the bullet shaped pigs. The new pigs were 12 in. long and 6.5 in. in diameter and did not have semi-rigid endplates. These pigs performed quite well and were used throughout the DT-1/OT-1 tests.

The procedure for purging and evacuating the hose was modified somewhat as a result of DT-1 testing. It became obvious that the pig inlet fitting was not required and that the pig could be pushed through multiple lengths of hose without difficulty. After inserting the pig into the adapter fitting, as shown in Figure 58, the coupling and end plug are re-installed and compressed air is introduced by simply connecting the air line to the same quick disconnect fitting used for the air ejector. An airhose adapter consisting of a double ended nipple is used between the female quick disconnect on the air hose and the female quick disconnect on the end plug.

Figure 58. Inserting pig into adapter fitting

During DT-1/OT-1, Foster-Miller personnel replaced the following failed components.

a. P-Q amplifier coil
b. Linear potentiometer
c. Solenoid control valve
d. Voice communication system microphone
e. Turntable bearing seals
f. Air compressor clutch.

9. HOSELINE DEVELOPMENT

The lightweight, 6 in. diam collapsible hose for the Petroleum Hoseline System was developed by Durodyne Inc. of Tucson, Arizona under subcontract to Foster-Miller.

These candidate hoseline constructions were considered:

a) Braided hose
b) Braided hose with longitudinal reinforcement
c) Loomed jacket construction.

The salient features of each of the candidate hoses are summarized in the following subsections.

9.1 Braided Hose

a) This construction contains a light layer of nylon reinforcement and two polyester braids. Weight can range from approximately 2.6 to 3.25 LB/FT depending on amount of rubber compound used.

b) Typical Test Values are as follows:

1. Actual Weight - 2.75 lb/ft
2. Tube Thickness - .060 lb/ft
3. Cover Thickness - .025 lb/ft
4. Wall Thickness - .0280 lb/ft average
5. Outside Diameter - 6.56 lb/ft average
6. .65% elongation at 125 psig
7. 2.3% swell at 125 psig
8. 5% elongation at 250 psig
9. 9.5% swell at 250 psig

c) The braided hose meets all performance requirements of specification.

9.2 Braided Hose with Longitudinal Reinforcement

a) Basically the same as previously mentioned braided construction except longitudinal polyester tire cord will be added.

b) Typical test values are as follows:

1) Outside diameter - 6.65 in. minimum possible
2) Burst pressure - 650 psig
3) 1% elongation at 150 psig
4) 2.86% diameter change at 150 psig
5) 3.97% elongation at 300 psig
6) 7.43% diameter change at 300 psig

c) This hoseline candidate is not as flexible and lightweight as the previously mentioned braided hose. Even with the addition of tire cord reinforcement, hose does not meet length change requirement at 300 psig proof pressure. This hose has excellent dimensional stability at 150 psig (working pressure) and will withstand end loading to approximately 6,000 lb with very little neckdown (approximately 4%).

9.3 Loomed Jacket Construction

This is a polyester/Kelvar jacketed hose similar to a fire hose, but with a cover. Most loomed jacket constructions produce poor dimensional stability and a high degree of twist. There are many processing problems involved in looming Kevlar yarn. Some work has been done on loomed jacket construction for Ft. Belvoir Development Contract with no success. One advantage, if processing problems (loom) could be overcome, long length, would pose no extreme production problems in our system.

9.4 Hoseline Selection and Production Techniques

The braided 2.75 lb/ft hose was selected for the PHS system. The Advancing Manual Technique was selected by Durodyne as the production technique based on experimental results using production equipment for braiding and nonstandard equipment for curing. Durodyne was able to produce good hose by this method, encountering no major problems that could not be resolved. Although the hose delivered for this program consisted of 50 ft lengths spliced together, the same manufacturing techniques could be used on 300 to 500 ft lengths.

9.5 Hose Assembly Fabrication and Assembly

Durodyne designed and fabricated a modified clamp ring coupling suitable for use with grooved end pipe coupling with MIL-C-10387. This coupling has a smooth constant outside diameter that nests neatly in the coupling pocket in the reel hub. A standard Victaulic(TM) style 77 gasket is used with the clamp ring.

A total of eight (8) 500 ft hoseline assembles including adapter fittings, clamp ring couplings, gaskets and end plugs were delivered under this program. Five of the hoseline assemblys were put on reels and used throughout DT-1/OT-1 without failure.

10. CONCLUSIONS AND RECOMMENDATIONS

The ability of the prototype Hoseline Reel Assembly to deploy and pick up lightweight 6 in. collapsible hoseline without damage at vehicle speeds up to 6 mi/hr was demonstrated with many different operators operating under automatic and manual control.

The ability to evacuate the hoseline and fully collapse it to a repeatable thickness that permits 500 ft wraps on the reel using the onboard air compressor and air ejector assembly was successfully demonstrated. The ability of the hoseline assembly including the couplings, end plugs and quick disconnect fittings to retain a vacuum over an extended period of time was also demonstrated.

Functional pig geometry and physical characteristics were identified and the ability to purge multiple lengths of hose at one time was demonstrated.

Based on the results of testing and training exercises at Foster-Miller and the subsequent DT-1/OT-1 testing it is concluded that the Hoseline Reel Assembly is a viable design concept for deploying hose and, more importantly, rapidly recovering hose and storing it in such a manner that it is ready for immediate redeployment. By storing the hose on a powered reel, 180° folds that are required in the existing flaking box hoseline systems are eliminated and hoseline life will be improved. The labor-intensive repacking process is also eliminated.

Although the prototype HRA worked reasonably well, a number of candidate areas for modification or redesign were identified.

As originally designed and built, the reel slot widths and the index rolls were too small to ensure that the hose would reel and unreel smoothly without grabbing or spilling off the rollers. The reel slot widths and index rolls and other elements that guide the hose from the reel to ground should be re-examined and resized to allow for such things as reel rim deformation and ensure that adequate clearances exist at all points. In DT-1, the reel slots and index rolls were made oversized intentionally to facilitate further investigation for operating these parameters.

The hydraulic system should be modified to incorporate a larger pump for the pinch rolls to replace the cam-shaft-driven pump. A larger pump could be belt driven or driven off a multiple output gear box. This change would eliminate the interaction between the primary (turntable) hydraulic circuit and the pinch rolls and simply the hydraulic circuit as well as the electrical circuit.

To reduce weight, it is recommended that a lightweight diesel such as the Deutz F2L511 be considered to replace the GMC 3-53 diesel. Also, the availability of a smaller, lighter air compressor should be investigated. If practicable, the air compressor should be located at about the same level as the diesel engine to lower the vertical center of gravity.

With a smaller diesel and air compressor, the engine enclossure could also be made smaller. In any event, it is recommended that the engine enclosure be made of aluminum and that the air flow passages be redesigned to eliminate line of sight sound paths and eliminate the perforated metal plates that now restrict air flow unnecessarily.

To further reduce weight, consideration should be given to using a lighter hose and preferably a hose with fewer splices.

It is recommended that the automatic control system be retained but that the dancer roll/linear potentiometer assembly be redesigned to provide a larger stroke with a higher spring rate and to replace the oil-filled wire around the potentiometer with a DC DVDT. Consideration should also be given to incorporating a surge loop perheaps similar to the concepts shown perhaps in Figure 59.

The pinch roll release mechanism should be strengthened, particularly the manual release levers. Improved guides should also be provided to prevent jamming of the hose behind the pinch rollers.

In conclusion, several of the recommended changes would reduce the vertical profiles, the weight, and improve the utility of the PHS system. A smaller air-cooled diesel engine will allow it and a smaller air compressor to be deck-mounted, lowering the center of gravity and reducing the size of the enclosures.

The center of gravity and profile would also be lowered by using a lighter hose with fewer splices. It has recently come to our attention that at least one manufacturer has developed a light (1 lb/ft) hose capable of meeting Petroleum Hoseline System requirements. Use of this kind of hose would dramatically reduce reel diameter, height, and weight, and provide for a generally lighter and more compact HRA.

A lighter frame and deck with readily adjustable bed clamps would reduce weight and add mounting versatility. The HRA could then be mounted on a variety of dedicated or undicated trailers, as well as trucks.

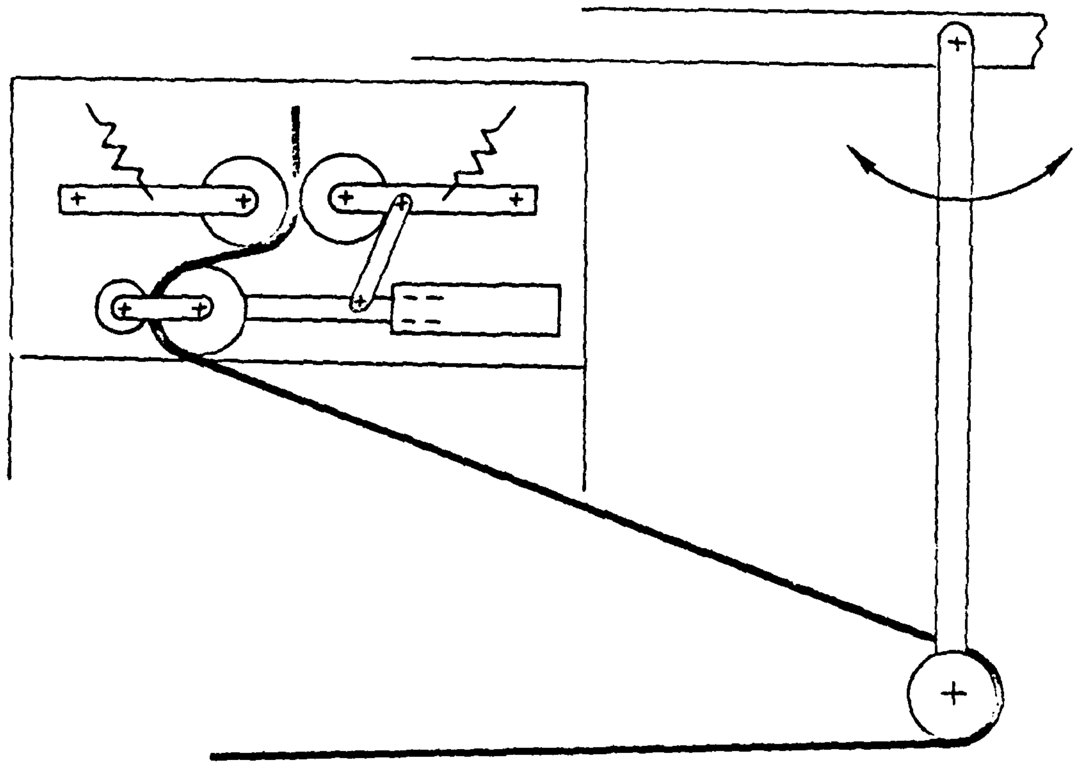


Figure 59. Concept for adding surge loop.

The hydraulic system for the next generation HRA will be manifolded as much as possible, with all components panel mounted in readily accessible locations.

APPENDIX A

INSTALLING AND OPERATING THE PETROLEUM HOSELINE SYSTEM

The Petroleum Hoseline System, comprised in part of the Hoseline Reel Assembly (HRA) and a number of reels of 6-in. petroleum hose, enters the theater of operations as a group of Milvan containers. To demonstrate the level of effort needed to operate the system, the steps of activating and using the system to lay hose will be enumerated. Skill levels beyond those outlined in the letter of agreement for developing the system are not needed.

A.1 Activating the Petroleum Hoseline System

To activate the Petroleum Hoseline System:

1. Secure a 5-ton military truck M813A2 with drop-side cargo bed. Secure adequate transportation for the hose as well.

2. Remove the drop-sides spare tire and tailgate in the motor pool.

3. Open the Milvan containing the Hoseline Reel Assembly and remove the blocking and bracing.

4. Pull the HRA from the milvan using the rear tiedown points at the base of the frame.

5. Locate the truck tiedown kit packed with the HRA. Break it open and check the contents against the parts list in the operating manual.

6. Using a forklift or crane, place the HRA on the M813A2 truck. The proper position on the truck is forward against the front panel and offset to the right approximately 8 in. as needed to get the tiedown rods of the tiedown clamps to clear the bed sides. Secure the tiedown clamps.

7. Using the information shown in Figure 60 and the operating manual, perform the daily maintenance checks on the HRA. Swing the index roll assembly outboard if need be to add diesel fuel. No fuel will be shipped in the unit. Prime the engine fuel system as described in the operating manual.

8. With the engine enclosure doors open, and someone watching the engine gauges, start the diesel from the operator's station. *Know where the emergency manual engine shutdown is*! Run the engine until the water temperature gauge needle starts to move. Shut the diesel down.

9. Using the operating manual as a guide, swing the index rolls into position for laying a hose. Pull the pinch rolls out from their storage position and lock in the operate position. Swing the loading platform out above the pinch rolls.

10. Start the engine and use the manual controls on the right of the operator's console to test the turntable's rotation, the pinch roll's rotation, and the air compressor's function. From the loading platform, test the turntable's free-wheeling and the index roll's vertical movement. Depress the reel lock foot pedal to be sure the pawls on the turntable work.

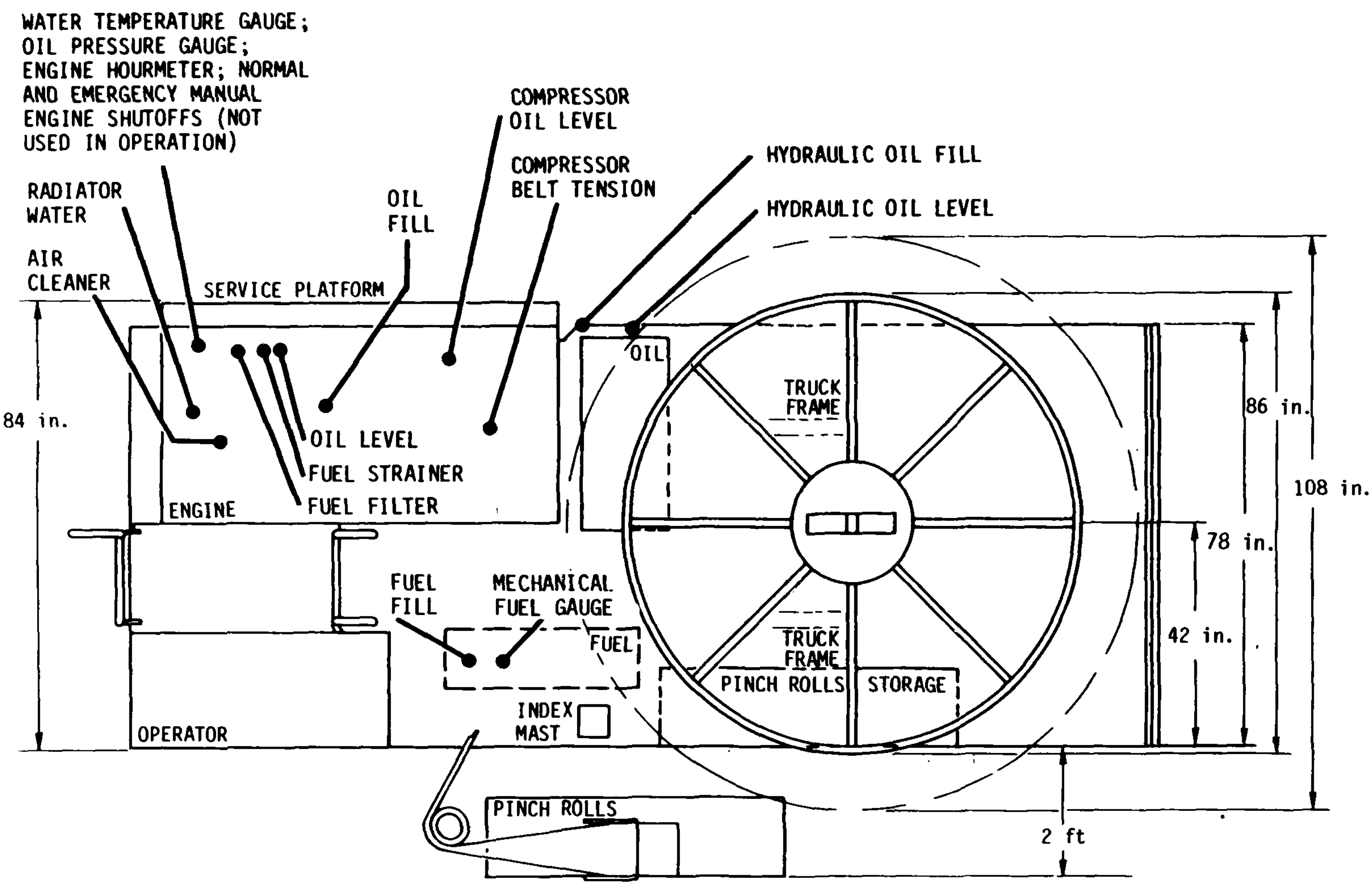


Figure 60. Operator service points.

11. Unpack the communications system hardware. Test the horn and the voice circuit.

12. Button up the engine enclosure and secure the service platform for travel.

13. Move the index rolls and the pinch rolls to their storage positions; close the hose loading platform.

The HRA is now ready for service.

A.2 Loading a Reel on the HRA

To load a reel on the HRA:

1. Open a Milvan containing hose and pull out the first stack of three dual reels.

2. Prepare to lift the top reel off the stack. A single lift point is provided in the center of the reel.

3. Locate the reel separation handle in one end of the rectangular hole. Pull on it to separate the top reel. Lift the reel with the crane or forklift while pulling.

4. Set the one dual reel aside.

5. Lift the remaining two dual reels and move them to the HRA.

6. Lower the reels onto the turntable; they will lock in place.

7. The HRA is now loaded.

8. Pull the second reel stack out of the milvan.

9. Separate the top dual reel following step three again.

10. Place this reel above the single reel from the first stack. Line up the rectangular slot and lower it into contact. The reels will latch together.

11. Lift the two dual reels and place them on their transportation. Do the same with the two dual reels remaining. Each dual reel with two 500 ft hoseline assemblies weighs 3550 lb. Therefore, up to five dual reels can be transported over the highway in a 5 ton truck.

A.3 Laying a Hose

To lay a hose:

1. Load a reel as detailed in subsection A.2.

2. Drive the truck to the site with the HRA in its storage condition.

3. Perform the daily maintenance checks.

4. Deploy the index rolls, the pinch rolls and the hose loading platform.

5. Activate the release latch to open the pinch rolls.

6. Start the engine.

7. Freewheel the turntable with the safety gate on the access ladder to the hose loading platform.

8. Starting with the upper most hose, release the securing strap holding the hose coupling to the reel. Remove and stow the strap.

9. With the index rolls adjusted to a comfortable height, feed the hose over the rolls and down through the pinch rolls. Be sure that the hose is twisted clockwise as viewed from the operator's station looking forward.

10. On the first hose, if at all practical, squeeze or fold the end of the hose back on itself and tie it off to prevent air infiltration into the hose at it is being laid.

11. Place hose end near the pump, pipe, or existing hose.

12. Close the pinch rolls.

13. Raise the index rolls so that the hose feeds straight to the first roll.

14. Close the safety gate after leaving the hose loading platform.

15. Move the main control switch on the operator's console to *AUTOMATIC DEPLOY*.

16. Depress the *AUTOMATIC START* switch.

17. Check to see that the pinch rolls tension the hose properly.

18. Tell the truck driver to proceed in low gear along the planned route.

19. Monitor the hose payout and stop the truck driver as the end of the hose comes up.

20. Hit the *STOP* switch after the truck stops.

21. Open the pinch rolls.

22. Freewheel the reel and feed the end of the hose to the ground.

23. Feed a second hose through the HRA rolls and close the pinch rolls. Tighten the hose on the truck and deploy the second hose.

24. Repeat procedure for deploying additional lengths of hose.

25. Connect all hose ends to pump, pipe, existing hose or tank.

26. Take the leftover parts: two plugs, one seal, and one clamp ring. Join them together and store them.

A.4 Recovering a Hose

A.4.1 How to Evacuate and Collapse the Hose (see Figure 61)

To evacuate and collapse the hose:

1. Pinch the near end of the hose with a clamp (Figure 62).

2. Partially pinch the end of the last hose with a clamp.

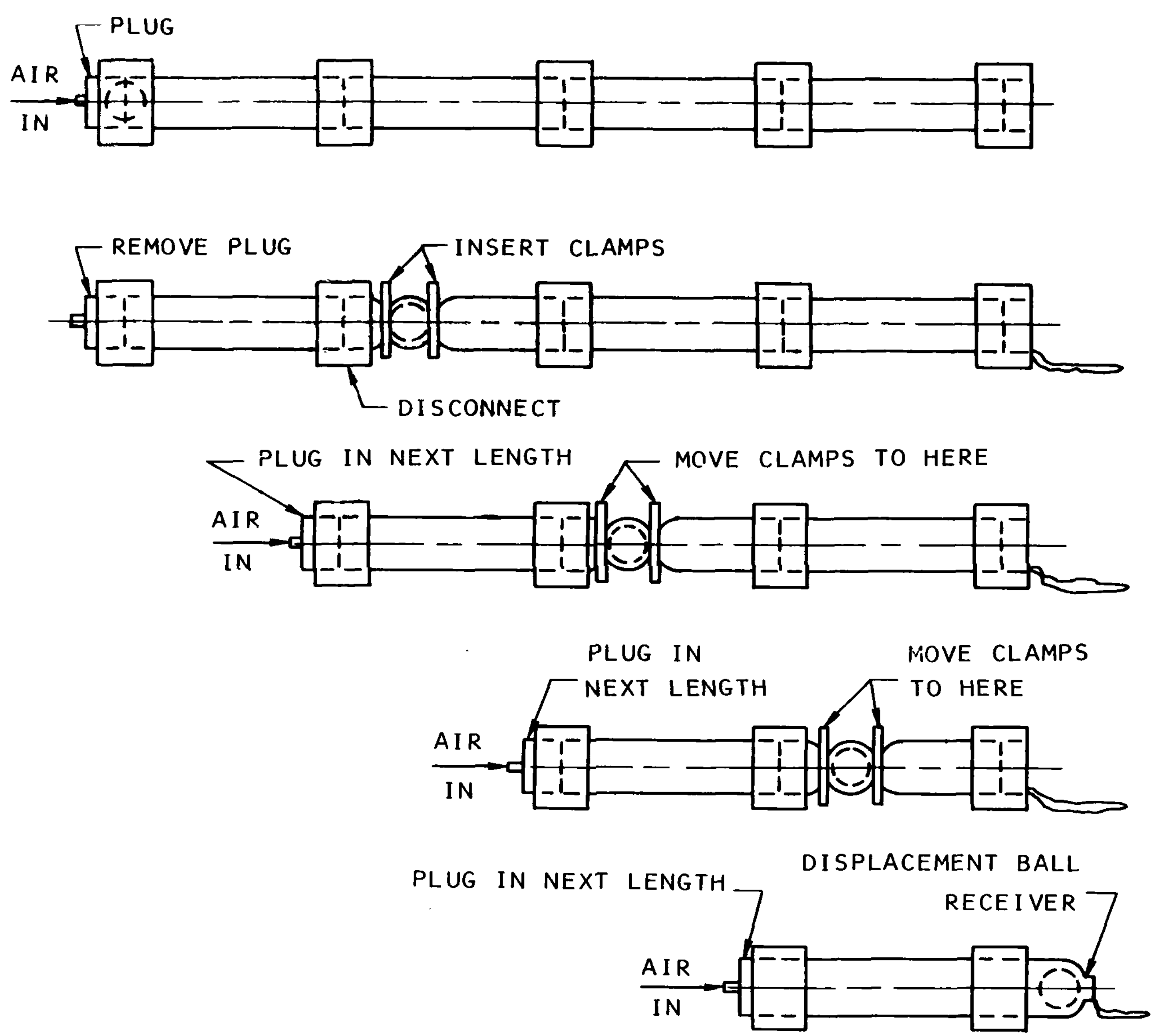


Figure 61. Plug method (one length at a time).

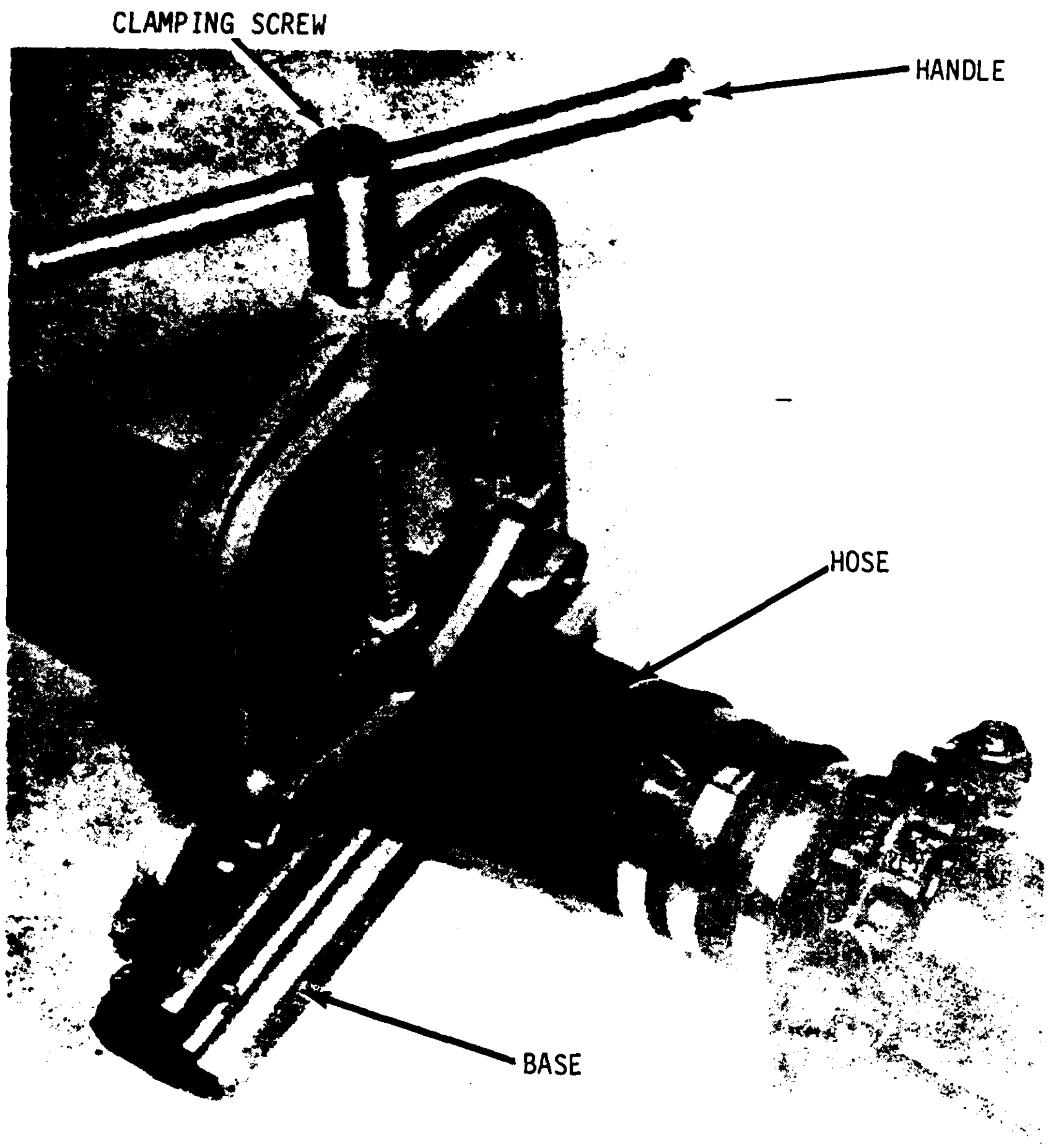


Figure 62. Portable hose clamp.

3. Remove the coupling from the near end of the hose, insert the evacuation pig and reinstall the coupling with an end plug.

4. Select *COMPRESSED AIR* on the HRA.

5. Connect air line to the plug end quick disconnect using the double ended nipple and turn air supply on to push the pig forward.

6. When the pig reaches the end of the hose (that is, when it is captured by the partial clamp), secure the pig by another clamp and then remove the air line. Vent the air pressure in the petroleum hoseline.

7. Break all hose couplings and install end plugs at both ends of each hose assembly. (See Figure 52)

8. Attach the ejector assembly to the near end of each hose in succession (Figure 63).

9. Turn air on, and evacuate the hose of air until the vacuum gauge reads 15 in. of mercury.

10. Remove the air line and ejection assembly.

The hose is now evacuated and collapsed and ready for recovery.

A.4.2 How to Recover the Hose

To recover the hose:

1. Turn the selector switch of the control panel to *MANUAL* and have the pinch rolls open.

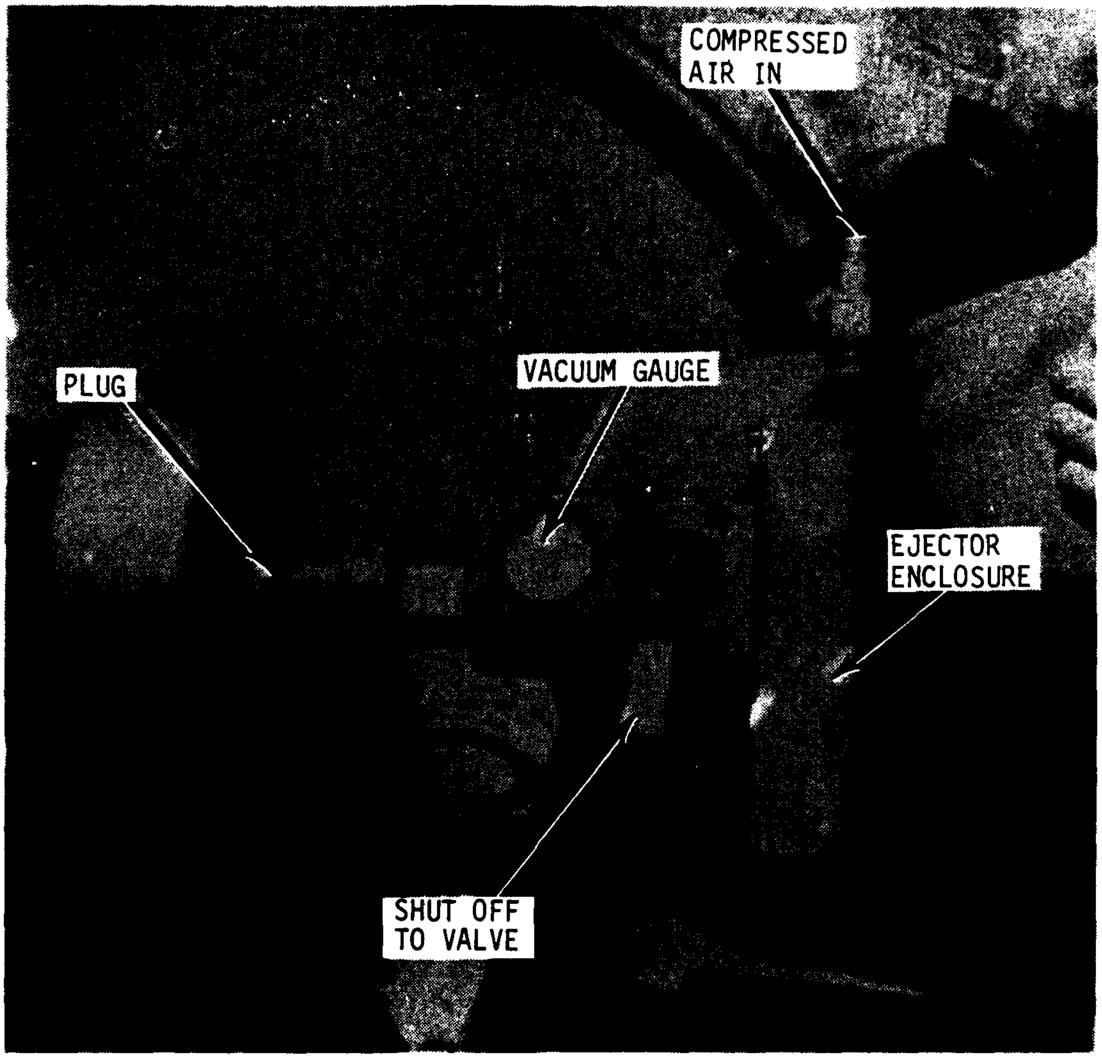


Figure 63. Ejector assembly.

2. Position the index rolls to the lower reel slot level.

3. Rotate the reel to gain access to the coupling in the hub.

4. Pass the end of the hose to the operator on the deck.

5. Place the end of the hose into the pocket and position the hose in the rolls.

6. Close the pinch rolls.

7. Use the manual (electric) joystick to operate the reel to take up any hose slack.

8. Select *AUTOMATIC PICK-UP* on the control panel and push the "*START*" button.

9. Signal the truck driver to advance forward. As the truck moves, the hose will be recovered automatically.

10. Watch out for the yellow band on the hose, and, when it appears on the ground directly below the operator's station, signal the driver to stop.

11. Turn mode selector switch to *MANUAL*, and open the pinch rolls.

12. Manually recover the remaining few feet of hose by operating the joystick control.

13. Attach the ratchet to the end of the hose, and tie it securely to the rim of the reel.

Proceed as outlined above to pick up any additional hoses.

APPENDIX B

TRAINING COURSE OUTLINE

FOR THE

PETROLEUM HOSELINE SYSTEM

Prepared by:

Foster-Miller, Inc
350 Second Avenue
Waltham, MA 0225-

Contract No. DAAK70-80-C-0216

April 1982

SECTION I - PREFACE

A.	Course:	Operation and Maintenance of the Petroleum Hoseline System Hoseline Reel Assembly
B.	Purpose:	To provide MERADCOM, TRADOC, TSARCOM and TECOM personnel with the skills and knowledge required to operate and maintain the Hoseline Reel Assembly in support of DT1/OT1 testing.
C.	Length:	2 weeks; 10 May 1982 through 21 May 1982
D.	Training Location:	Foster-Miller, Inc. 350 Second Avenue Waltham, MA

SECTION II - SUMMARY

Course - Operation and Maintenance of the Petroleum Hoseline System Hoseline Reel Assembly

Hours - 80

Subject:	Hours	Annex	Page
A. Academic Subjects			
Introduction	1.0	A	
Elements of the Petroleum Hoseline System (PHS)	2.0	B	
Operation of the Hoseline Reel Assembly (HRA)	20.0	C	
Maintenance of the HRA	34.0	D	
Shipping, Storing and Installing the HRA	4.0	E	
Subtotal	61.0		
B. Non-academic Subjects			
Inprocessing	8.0		
Outprocessing	8.0		
Open Time	3.0		
Subtotal	19.0		
Total	80.0		

C. Recapitulation

1. Security Classification:

Top Secret Restricted Data	0
Top Secret	0
Secret Restricted Data	0
Secret	0
Confidential	0
Unrestricted	80

2. Type of Instruction:

Classroom
Practical Exercise

SECTION III - BODY

Course - Operation and Maintenance of the Petroleum Hoseline System Hoseline Reel Assembly

Academic Subjects - 80

Annex Title and Subjects:	Hours	Annex	Page
Introduction		A	
U.S. Army Petroleum Requirements and Methods of Delivery	0.3		
Technical Manuals	0.2		
Facility and Hardware Tour	0.5		
Annex Total	1.0		
Elements of the Petroleum Hoseline System		B	
Pump	0.1		
Hose	0.4		
Hoseline Repair Kit	0.4		
Displacement and Evacuation Kit	0.4		
Hoseline Reel Assembly	0.7		
Annex Total	2.0		
Operation of the Hoseline Reel Assembly (HRA)		C	
Nomenclature and Functions of the HRA	2.5		
General Tasks and Duties of Operator and Crew	1.5		
Operating the HRA	16.0		
Annex Total	20.0		
Maintenance of the HRA		D	
Preventive Maintenance Checks and Services	8.0		
Corrective Maintenance	18.0		
Perform Maintenance	8.0		
Annex Total	34.0		
Shipping, Storing and Installing the HRA		E	
Installing the HRA	2.0		
Preparation for Storage	2.0		
Annex Total	4.0		

SECTION IV - ANNEXES

ANNEX A - Introduction

Hours - 1.0

Purpose - To acquaint the student to the need for the Petroleum Hoseline System, particularly the Hoseline Reel Assembly; to introduce the technical manuals; to expose the student to the Hoseline Reel Assembly; and, to familiarize the student with the training facility.

A-1 - U.S. Army Petroleum Requirements and Methods of Delivery

Hours: 0.3

Objective: Establish the need for the Petroleum Hoseline System.

A-2 - Technical Manuals

Hours: 0.2

Purpose: To introduce and familiarize student with the technical manuals which will be the primary text for the course.

A-3 - Facility and Hardware Tour

Hours: 0.5

Objective: To expose the student to the Hoseline Reel Assembly hardware for the purpose of associating subsequent classroom instruction with the physical hardware.

SECTION IV - ANNEXES (Continued)

ANNEX B - Elements of the Petroleum Hoseline System (PHS)

Purpose - To provide the student with a knowledge of the nomenclature, function, performance capability and physical characteristics of the following major elements of the PHS:

B-1 - Pump

Hours: 0.1

Objective: To provide the student with a knowledge of the pump's function, physical characteristics and performance capability.

B-2 - Hose

Hours: 0.3

Objective: To provide the student with a knowledge of the hoseline's physical characteristics and performance capability.

B-3 - Hoseline Repair Kit

Hours: 0.2

Objective: To provide the student with a knowledge of the component parts of the hoseline repair kit, their use, application, and physical characteristics.

B-4 - Displacement and Evaluation Kit

Hours: 0.4

Objective: To provide the student with a knowledge of the components of the displacement and evacuation kit, their function and physical characteristics.

B-5 - Hoseline Reel Assembly (HRA)

Hours: 1.0

Objective: To provide the student with a knowledge of the HRA function, physical characteristics and performance capabilities.

Reference TM-5-3835-218-14, Chapter 1, Section II.

ANNEX C - Operation of the Hoseline Reel Assembly (HRA)

Purpose - 1) To provide the student with a knowledge of the major subassemblies of the HRA, their function, location, performance and physical characteristics.

2) To define the general duties of the operator and crew.

3) To teach the student how to operate the HRA.

C-1 - Nomenclature and Functions of the HRA

Hours: 2.5

Objective: To provide the student with a knowledge of the nomenclature, function, location, and characteristics of the following subassemblies: frame; turntable and turntable drive; reel; engine enclosure; pinch roll assembly; index roll assembly; control station; communication system.

Reference TM 5-3835-218-14, Chapter 1, Sections II and III.

C-2 - General Tasks and Duties of Operator and Crew

Hours: 1.5

Objective: To define the general tasks assigned to the vehicle driver, the HRA operator, and the ground crew.

C-3 - Operating the HRA

Hours: 16.0

Objective: To teach the student how to operate the HRA under normal and unusual conditions. Several hours of student operation of the HRA will be provided.

Reference TM 5-3835-218-14, Chapter 2, Sections I, III, and IV.

SECTION IV - ANNEXES (Continued)

ANNEX D - Maintenance of the HRA

Purpose - To provide the student with a knowledge of the preventive and corrective maintenance procedures required to support operation of the HRA.

D-1 - Preventive Maintenance Checks and Services

Hours: 8.0

Objective: To teach the student the preventive maintenance procedures required at the operator and direct support level, including the frequency at which service is to be done. To allow the student to practice preventive maintenance procedures on the HRA.

Reference TM 5-3835-218-14, Chapter 2, Section II; Chapter 3, Sections I and III.

D-2 - Corrective Maintenance

Hours: 18.0

Objective: To instruct the students in the troubleshooting procedures and corrective maintenance procedures required to support operation of the electrical systems and hydromechanical systems of the HRA. Troubleshooting techniques and procedures will be emphasized. To allow the student to perform selected corrective maintenance procedures on the HRA.

Reference TM 5-3835-218-14, Chapter 3, Sections IV and V.

SECTION IV - ANNEXES (Continued)

ANNEX E - Shipping, Storing and Installing the HRA

Purpose - To provide the student with a knowledge of the procedures for installing the HRA on the truck bed and preparing the unit for shipping and storage.

E-1 - Installing the HRA

Hours: 2.0

Objective: To teach the student what service to perform upon receipt, how to install the HRA on the vehicle bed with emphasis on safety procedures and the preliminary servicing and adjustment procedures.

Reference TM 5-3835-218-14, Chapter 3, Section VI.

E-2 - Preparation for Storage

Hours: 2.0

Objective: To provide the student with a knowledge of the procedures for preparing the HRA for:

a. Administrative storage
b. Intermediate storage
c. Long-term storage.

Reference TM 5-3835-218-14, Section VI.

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