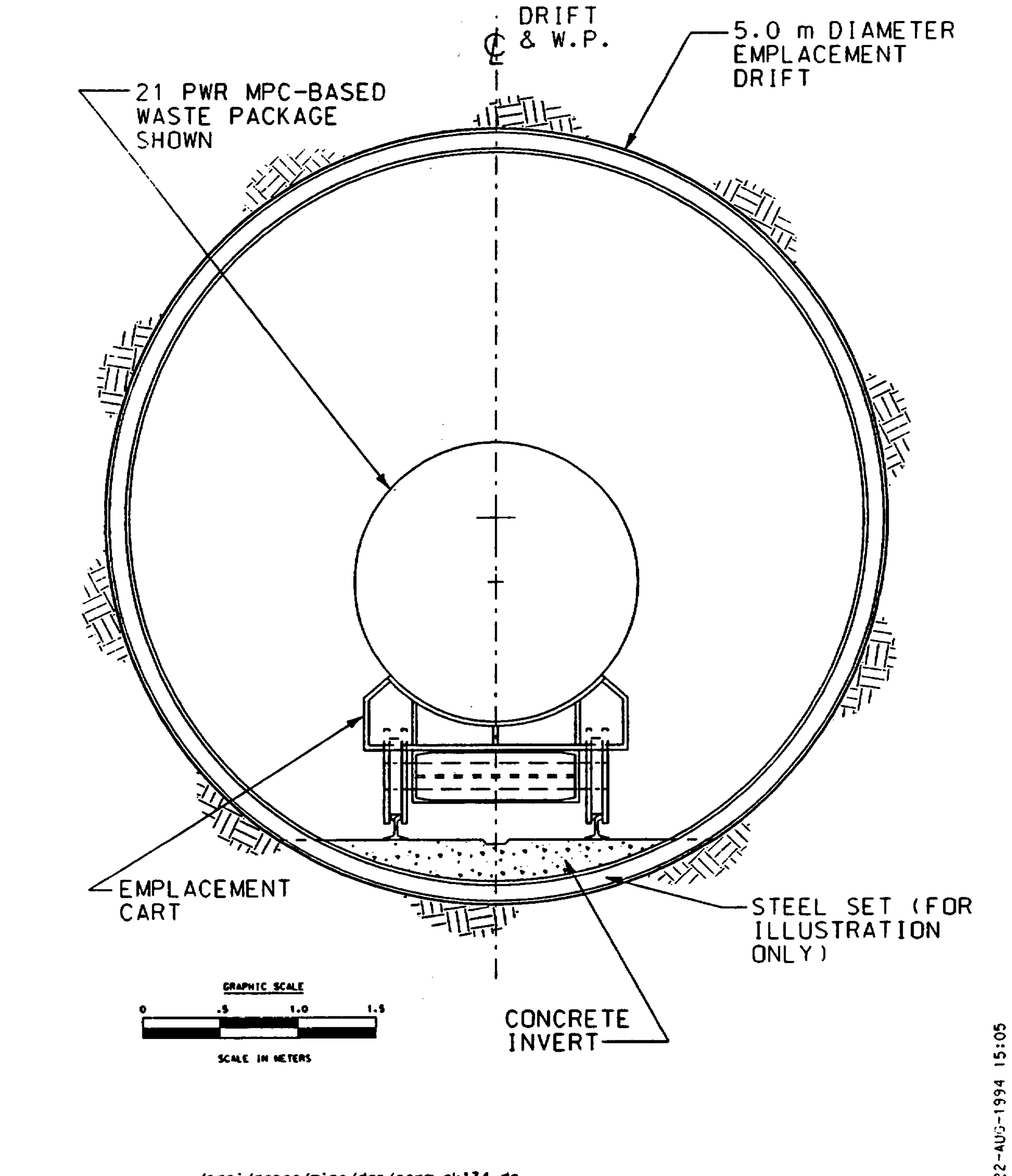


Figure 8.5.2-1. Emplacement In-Small-Drift-On-Rail Cart - Cross Section

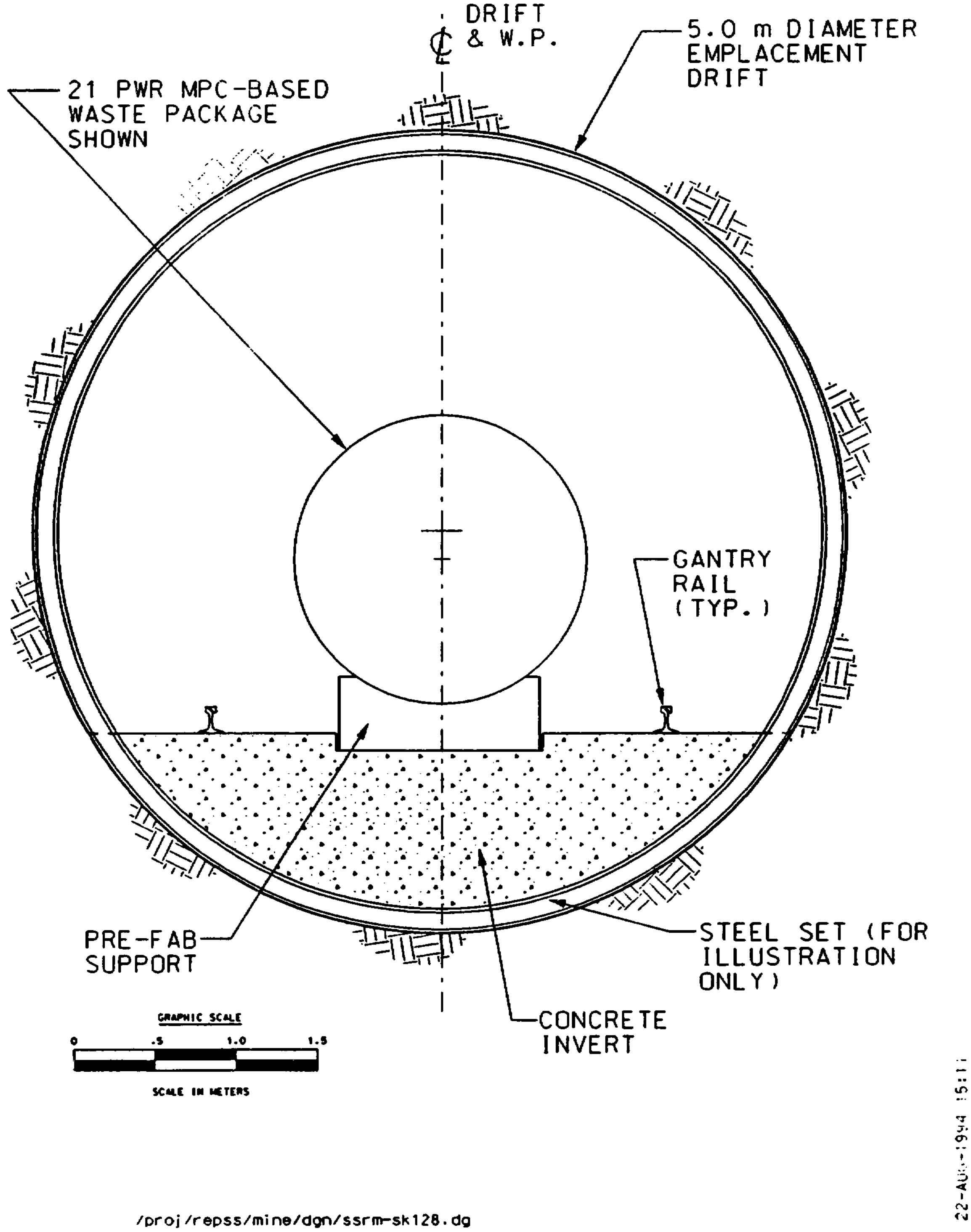


Figure 8.5.2-2. Emplacement In-Small-Drift-On-Pedestal - Cross Section

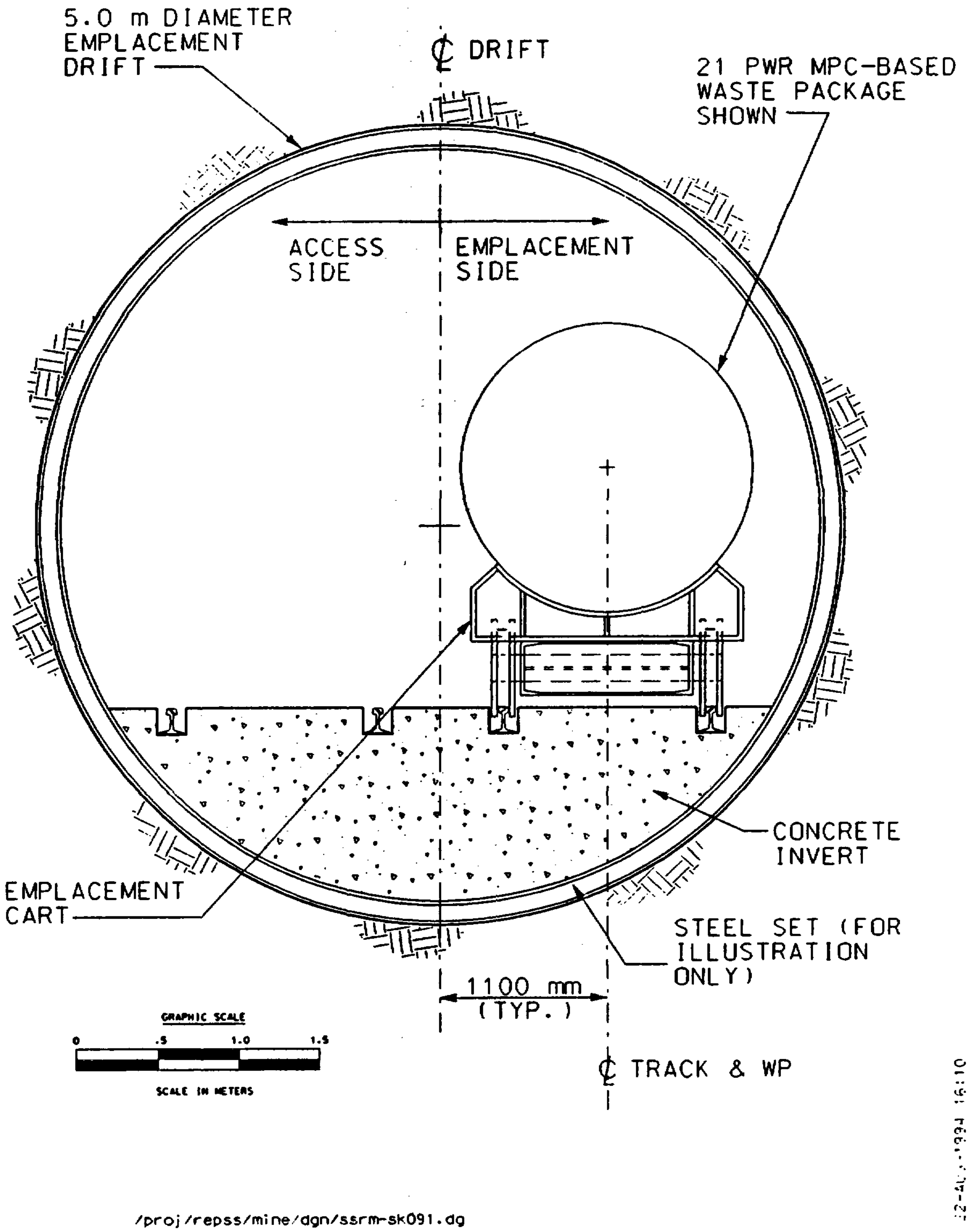


Figure 8.5.2-3. Emplacement Off-Center-In-Drift-On-Rail Cart - Cross Section

8.6 REPOSITORY SUBSURFACE LAYOUT

Two layout concepts are discussed in this report and are applicable to in-drift emplacement of MPC-based WPs. The concepts are presented in varying degrees of detail in the subsections below. One concept, termed Option I, is considered as a refinement of the ESF/repository interface layouts made in FY 1993 and early 1994. These layouts were originally discussed in Section 8.1. A presentation of the general layout features and design objectives for the Option I concept is made in Section 8.6.1. The second concept, termed Option II, used many attributes of the Option I concept but contains several areas of significant difference which are compared. An interim layout is selected from the two in which to base the presentation of design concepts in later sections of the report, and a detailed functional description of all openings in the interim layout is presented. Finally, a design concept for maximizing the potential emplacement capacity of the primary area of Area 1 (refer to Section 8.2.1.4) is outlined.

8.6.1 General Layout Features and Design Objectives

Consistent with past repository conceptual designs, a primary feature guiding development of repository ACD layouts is provision for the separation of subsurface ventilation systems, a basic program requirement listed in 10 CFR 60.133(g)(3). Strict compliance with this requirement leads to a design that divides subsurface operations into two separate systems, separated by physical barriers. Operations in one half, the "development side," involve the construction of emplacement drifts and other work that prepares dedicated areas for emplacement of nuclear waste. Operations in the other half, the "emplacement side," include the actual transportation of the nuclear waste to the subsurface and its emplacement. Each "side" has two separate accesses to the surface that also serve as primary ventilation airways and as alternate means of egress.

Another feature included in the ACD layouts presented in this report results from a program requirement directing the development of an integrated ESF/Repository design (DOE, 1985). Pre-ACD efforts culminated in preparation of the Exploratory Studies Facility Alternatives Study (ESFAS) (SNL, 1991a), a comprehensive assessment of 34 different options for development of an integrated ESF/Repository design. The document (YMP, 1991a) that brought forward results from the ESFAS as a basis for Title I ESF design, stressed the need to pursue development of ESF/Repository layouts that incorporate <u>all</u> of the favorable design features identified in the ESFAS (none of the 34 options met all of the favorable design features). Consistent with recommendations made therein, an enhanced ESF layout that met all of the favorable features identified in the ESFAS, and that offered numerous constructibility/operability and scientific advantages to the program, was developed by the M&O and submitted to the YMP Change Control Board (CCB) in 1993. Entitled, "Description and Rationale for Enhancement to the Baseline ESF Configuration," (M&O, 1993e) it was accepted by the CCB in FY 1994 and has been incorporated into YMP's baseline documents. A report describing the conceptual repository layout that was integrated with the enhanced ESF layout was submitted to DOE in December 1993 (M&O, 1993b). The repository concept presented in that report formed the primary basis for a set of six

ESF/Repository interface drawings that were submitted to DOE in February 1994 (M&O, 1994o), and that are in the process of being incorporated into YMP's baseline documents.

Besides addressing the fundamental program requirements listed in Section 3.2, and the general features described in the preceding paragraph, development of the repository layouts and operational concepts described in the sections that follow were predicated on incorporation of the design assumptions (some might also consider these to be design objectives or concepts) listed below into functional repository subsurface designs. Most of the items listed are CDA assumptions (M&O, 1994m) that are more fully developed interpretations or ideas representing proposed methods of complying with various program requirements. References to specific requirements listed in Section 3.2 and/or specific CDA assumptions are provided inside brackets where appropriate.

All of the assumptions listed will require verification as the site characterization and ACD programs develop. Because the assumptions work together to provide the logistical framework for the integrated layouts described herein, they are considered to be used throughout the subsurface sections of this report unless otherwise noted.

A. Utilize Primary Area Identified by Previous Work - Develop a repository layout that generally fits and utilizes most of the region identified as Area 1 in Figure 8.3.2-3. (M&O, 1994m, Key 022)

B. Utilize TSw2 Thermomechanical Unit for Repository Horizon - Location of an upper boundary for the repository horizon is principally influenced by the requirement to provide a minimum overburden of 200 m (10 CFR 960.4-2-5 (d)); an upper stratigraphic control is not clearly defined. Current borehole data indicates that an upper limit based on an increase in lithophysae porosity may exist in the TSw1 unit from 12 to 49 m above the TSw1/TSw2 upper contact (M&O, 1994s). However, even though lithophysae porosity of the TSw1 unit appears greater than the TSw2, there is as yet no definitive basis for favoring one unit over the other. Also, differences between the TSw1 and the TSw2 units on the basis of rock quality are not consistent. However, due to uncertainty about differences in mechanical and thermal characteristics between TSw1 and TSw2 units, the TSw1/TSw2 contact is assumed to be an upper limit for the repository horizon, so long as (with the exception of main ramps and shafts) all subsurface openings conform to the minimum 200 m overburden requirement. The TSw2 unit provides adequate thickness for the repository and there do not appear to be stratigraphic zones within the TSw2 that would limit repository development. The TSw2/TSw3 contact is an assumed lower limit to repository development that helps maximize the distance above the water table in the primary area and the thickness of underlying zeolitic strata. [M&O, 1994m, DCSS 003; RDRD: 3.7.5.H; 3.7.5.E.3; 3.7.5.E.7]

C. Utilize Lynx Model for Definition of Geologic Surfaces - Structural contour, surface topography, water table, and other base maps included in Section 5, and originally defined in a 1994 M&O analysis (M&O, 1994s), were used in developing the repository layouts included herein. These maps were developed and plotted using the Lynx computer model, a program that has been approved for use in quality affecting work. However, the bulk of the geologic borehole data used by the model were not collected under an approved QA program. While much of the borehole data are of indeterminate quality, the information is the best that is available and its use is consistent with past YMP-conceptual design efforts. Assume that products generated by the Lynx model are of sufficient accuracy to support development of conceptual repository layouts and integrated ESF layouts that will not require significant changes as more geologic data become available and/or new geologic models evolve.

D. Maintain Linkage with Previous Work - Develop a layout that accomplishes objectives regarding ESF/Repository integration as outlined in the ESFAS (SNL, 1991) and that, as a minimum, embodies all of the favorable features identified for Option 30 in that document. Maintain the portal location and the azimuth of the North Ramp as currently defined in ESF Title II design (YMP, 1994b). [RDRD: 3.7.5.E.4]

E. Standoff from Faults - To the extent practical, situate main drifts and emplacement drifts in such a manner that they are not intersected by the primary faults shown on Figures 5.1.2-3 and 5.1.2-4. Based on engineering judgment, allow a minimum 120 m standoff between the main trace of the Ghost Dance Fault and main drifts situated to the west of the fault. Allow 60 m minimum standoff for main drifts on the east side of the Ghost Dance and from other main faults, the assumption being that information gathered during site characterization will provide sufficient definition of actual fault locations and character at the repository horizon to make greater standoff distances unwarranted. [M&O, 1994m, key 023; RDRD: 3.7.5.E.2; 3.2.6.2.5; 3.7.5.E.3; 3.7.5.E.7]

F. Utilize Flat/Horizontal Gradients in Emplacement Drifts - Orient emplacement drifts with flat gradients in order to maximize safety and operational stability of emplacement and retrieval processes. [M&O, 1994m, DCSS 009; RDRD: 3.2.5.2.2.A; 3.2.1.4.B; 3.7.5.E.1; 3.7.5.H]

G. Use an In-Small-Drift Emplacement Concept - As presented in Section 8.5.1.1, 5.0 m diameter emplacement drifts can accommodate several variations of in-drift emplacement. Lacking definitive evaluations necessary to support selection of a specific emplacement concept, use 5.0 m excavated diameter emplacement drifts in the preparation of ACD layouts in order to maintain flexibility in design. Besides the obvious advantages that small diameter drifts offer in terms of opening stability and ground support requirements, this concept also helps maximize rates of progress in the construction of emplacement drifts while minimizing the amount of excavated tuff, all of which lends itself to minimizing the cost of repository development operations. Additionally, the various concepts support retrieval in a straightforward manner and could be automated relatively easily. [M&O, 1994m, key 012, 016, 017; RDRD: 3.2.5.2.2.A; 3.7.5.E.2; 3.2.6.2.5; 3.7.5.E.5; 3.7.5.E.1; 3.2.1.4.B; 3.7.5.O.1; 3.7.5.D; 3.7.5.P.2; 3.7.5.P.3]

H. Use Conventional Rail Transport for both Emplacement and Development Operations - Larger, heavier WPs make transport on conventional rail systems a practical option or solution. In addition, TBM operations are almost universally supported by railbound equipment. Conventional rail (sometimes termed adhesion rail) systems rely on the friction developed between steel wheels and steel rail to provide the resistance necessary to facilitate both starting (acceleration) and stopping (deceleration) of the trains. To a large extent, the safety of operations in these systems relates to the maximum gradient upon which the trains are required to operate. For purposes of this layout, limit the maximum grade on main ramps to 3.0 percent or less and the maximum grade "on block", e.g., main drifts used for emplacement drift access, to 2.0 percent or less. [M&O, 1994m,DCSS 009; RDRD: 3.7.5.E.1; 3.7.5.F.5; 3.7.5.P.2]

I. Maintain Straight Emplacement Drifts - Each variation of in-drift emplacement described in earlier report sections requires the use of a rail system to carry the heavy, MPC-based WPs inside the emplacement drifts. One of the more likely upset conditions that can occur using rail haulage is derailment of the WP carrier. To the extent possible or practical, the emplacement drifts should be designed perfectly straight so that the likelihood of a derailment is minimized, thereby enhancing the reliability of transport inside the drift. For those emplacement concepts that use a permanent cart for both moving and final support of the packages, straight drifts represent a significant cost savings as the carts do not have to be manufactured with any turning capability, thus greatly simplifying their design and fabrication requirements. This feature also has significant implications in terms of radio- or laser-based control systems that might be considered in future work. Excavation using TBMs is also simplified. [RDRD: 3.2.5.2.2.A; 3.7.5.E.5; 3.7.5.E.1; 3.2.1.4.B; 3.7.5.O.1; 3.7.5.D; 3.7.5.P.2; 3.7.5.P.3]

J. Maximize the use of TBMs as the Principal Excavation Tool - The layout should accommodate excavation by TBM as the primary development tool, both for main drifts and emplacement drifts. Where practical, curves or other features should permit muck removal by conventional conveying systems. For long term installations, assume (based on engineering judgment) that curves should use a 305 m radius, but not less than 180 m if use of the longer radius is impractical. [M&O, 1994m, DCSS 010; RDRD: 3.7.5.G.2; 3.2.5.2.2.B]

K. Minimize the number of Main and Secondary Access Drifts - Previous designs (SNL, 1987a; PBQ&D, 1989) have utilized extensive systems of main and secondary access drifts that tend to consume space, create potential thermal perturbations, prolong construction schedules, and ultimately, raise costs. A simplified layout that reduces the number of main and secondary access drifts while meeting all of the fundamental program and safety requirements is considered (engineering judgment) to be highly desirable. [RDRD: 3.2.5.2.2.A]

L. Provide a Common Drainage Point for all Main Drifts - Ensure that all main drifts are sloped to facilitate water drainage to a common underground location for pickup and removal to the surface. [RDRD: 3.7.5.I; 3.2.3.2.2.A.11.a]

M. Waste Inventory - Assume a waste stream totaling 70,000 MTU. [M&O, 1994m, Key 003,005]

N. Areal Mass Loading (AML) - Rather than adopt a specific AML as a design basis, develop a repository layout that utilizes essentially all of the primary area (Area 1 in Figure 8.3.2-3). Calculate the storage capacity in MTU based on the resulting emplacement area available using a low AML of 25 to 35 MTU/acre and using a high AML of 80 to 100 MTU/acre. [M&O, 1994m, Key 019]

O. Intermingling of Waste - Assume that HLW packages will be delivered on an as-needed basis so that they can be positioned in-between the SNF packages in the emplacement drifts, eliminating the need for additional emplacement drifts to accommodate the HLW inventory. Further, assume that there will be no restrictions regarding the intermingling of waste forms in the drifts.

P. WP Dimensions - Assume that the largest WP is 1802 mm in diameter, 5642 mm long, and weighs approximately 86,500 kg when loaded with 21 PWR SNF assemblies and filler material. [M&O, 1994m, EBDRD 3.7.1.J.1 and 3.7.1.J.2]

Q. Subsurface Transport of WPs - Assume that the WPs will be transported along access routes in the subsurface inside a specially designed transport cask shielded to reduce radiation exposure to "stand-beside" levels. Assume that the packages are mounted on the emplacement carts and loaded into the cask in the waste handling building on the surface. [CDA Key 032, 033; DCS-003; RDRD: 3.2.5.2.2.B]

R. Emplacement Operations Equipment and Procedures - Assume that the conceptual emplacement operations and equipment discussion provided in Section 5.1.7.4.2 of M&O, 1993b, represents a workable concept that could be engineered to provide adequate levels of reliability and personnel radiological safety. [RDRD: 3.2.5.2.2.A; 3.2.5.2.2.B]

S. Construction Materials in Emplacement Drifts - Assume that the use of a permanent, cast-in-place concrete invert, permanent steel rail, and steel or concrete ground support elements in the emplacement drifts does not pose insurmountable performance problems in terms of long term waste isolation. [M&O, 1994m, DCSS 027; RDRD: 3.7.5.E.1; 3.7.5.E.7; 3.7.5.P.3]

T. Backfilling of Emplacement Drifts - Assume that backfilling of the emplacement drifts will not be required, but do not design a layout that precludes the possibility of being able to backfill if later work indicates a need for backfilling. Assume that if backfilling of the emplacement drifts is required, then it can be postponed until after the retrieval option is no longer a consideration. Also, assume that a backfill material will be selected that can either be pumped up to 700 m horizontally using conventional concrete pumping or similar equipment, or pneumatically conveyed over similar distances, and that the drift will not have to be completely filled to the crown. [M&O, 1994m, Key 046, RDRD: 3.7.5.E.2; 3.7.5.E.5]

U. Emplacement Drift Spacing - Adopt an emplacement drift spacing of 22.5 m, to be used as an example in describing the operational interfaces of various drifts and for diagrammatic purposes, recognizing that drift spacing must be determined in conjunction with optimization of a system comprised of parameters that also include package spacing, drift diameter, thermal loading, thermal goals, potential variability in thermal characteristics of the waste stream, etc. [RDRD: 3.7.5.P.1]

V. Standoff of WPs from Access Drifts - Defined as the distance that WPs are set back from the nearest accessway, a thermal buffer, or "standoff distance" will limit the maximum rock temperature in the access drift. This is considered important in terms of both the working environment in the access drift and the influence that elevated temperatures might have on the stability of the drift. Based on results from various studies as discussed in Section 8.3.3, assume a standoff distance of 35 m between the centerline of the closest SNF WP and the closest rib in both the waste handling and the perimeter main drifts. This is considered fairly conservative since studies performed to evaluate this parameter have recommended similar distances and have not taken into account the cooling effect of ventilation air in the access drifts. [M&O, 1994m, DCSS 023; RDRD: 3.7.5.E.1; 3.3.6.1.B]

W. Maximum Extraction Ratio - To promote long term opening stability and for purposes of conservatism, assume an upper limit extraction ratio of 30 percent in the emplacement drift area. This limit does not apply in the mains or other areas where waste is not emplaced. [M&O, 1994m, DCSS 006; RDRD: 3.7.5.E.2]

X. Standoff from Vitrophyre - To prevent heating of the TSw3 and CHn units above the thermal goal of 115°C (Table 8.3.1-1), assume that a standoff of approximately 30 m between the WPs and the TSw2/TSw3 contact is sufficient when the nearest approach is along an edge of an emplacement area, but that the majority of the emplacement area should be at least 60 m above the TSw2/TSw3 contact. [RDRD: 3.7.5.E.3; 3.7.5.E.7]

Y. Secondary Excavation Methods - As discussed in Section 8.4.2.1, currently available roadheader type mechanical excavation equipment offers the flexibility needed for performing miscellaneous, low-volume secondary excavation tasks, but is not well suited for excavating rock with physical characteristics as anticipated in the TSw2 unit. Also discussed is the fact that research being conducted by the Colorado School of Mines (under a YMP contract) involving adaptation/modification of current cutter disc technology to roadheader machines, and development of a design for a specially configured alcove miner, promises to augment the capabilities of those secondary mechanical excavation methods that offer the flexibility necessary for creating custom excavation profiles. It is assumed that this or similar equipment will be fully developed, tested, and will be available for repository construction, thereby eliminating the need to utilize drill and blast techniques to perform secondary excavation tasks. [M&O, 1994m, DCSS 005; RDRD: 3.7.5.G.2]

Z. Emplacement Drift Orientation - Assume that, relative to in-situ stress and joint orientations, the alignment of openings such as the main drifts and ramps, which can be accessed and maintained throughout all phases of the repository program, is considered to be of considerably lower priority than the alignment of emplacement drifts, where heat and radiation pose formidable problems if maintenance is required. Based on the discussion of preferable drift orientations as outlined in Section 8.2.1.3, assume a bearing for emplacement drifts of N72W. [M&O, 1994m, DCSS 001; RDRD: 3.7.5.E.2]

AA. Monitoring of Emplacement Drifts - Assume that monitoring and instrumentation equipment can be designed to travel along trackways suspended from the crown of the emplacement drift or in other locations that permit necessary monitoring activities to be conducted remotely, but can be removed as necessary to allow personnel to perform routine maintenance on this equipment without physically entering the emplacement drift. [RDRD: 3.2.5.2.2.B; 3.7.5.P.3]

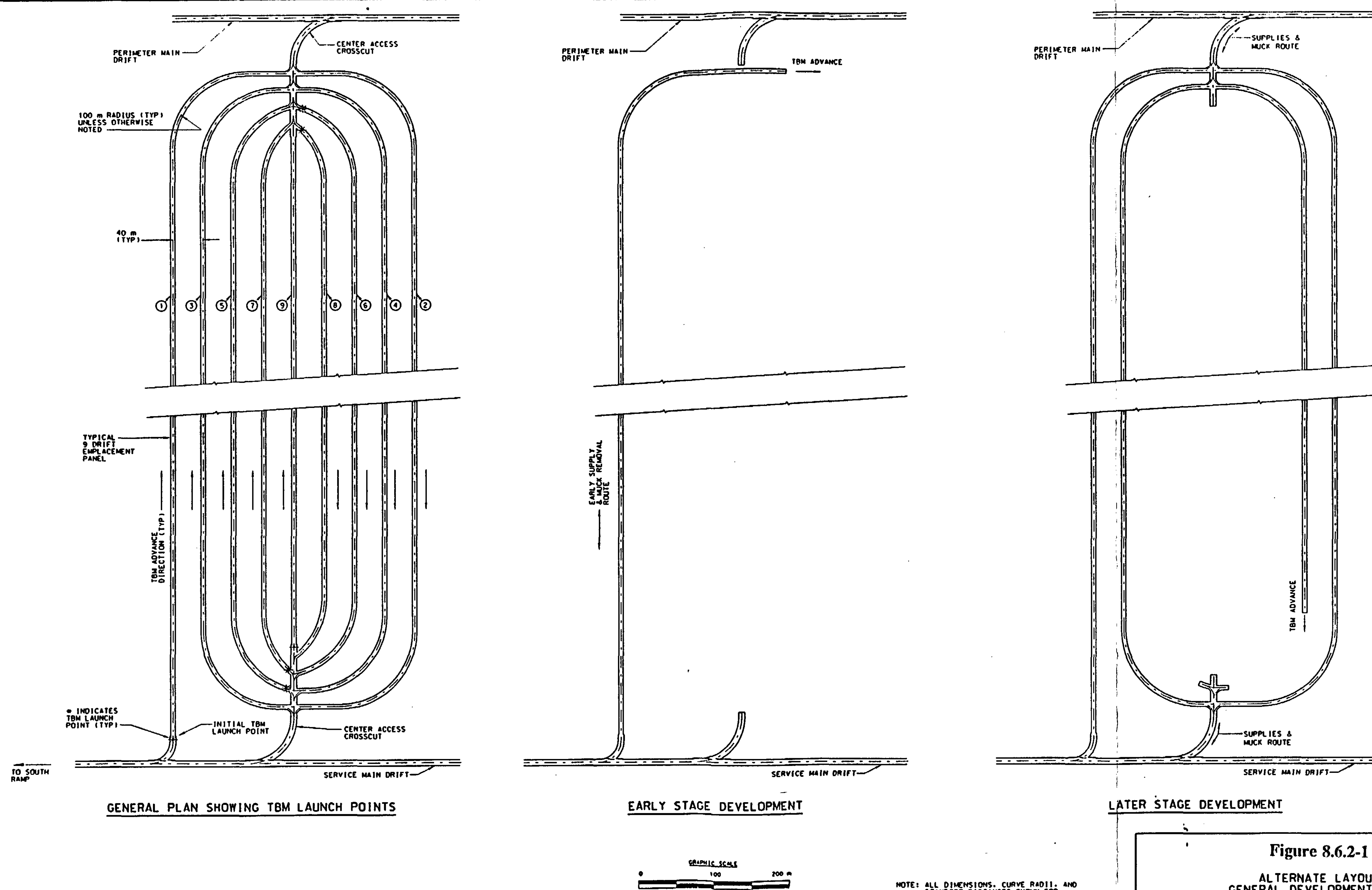
BB. Air Quality - Assume that ventilation of all excavation operations will be provided by exhausting auxiliary fan/duct systems that will discharge through dust scrubbers into the service main and/or launch main airstreams. Assume that the efficiency of the scrubbers is sufficient to allow routine maintenance, travel, and other work to be conducted without special concerns regarding worker health and safety related to air quality in these openings.

8.6.2 Alternative Layout Configurations

Alternative layout configurations must be investigated as a part of repository ACD to address variations precipitated by different emplacement concepts, opening sizes, and layout objectives. Two different general layout configurations have been developed that are applicable to the emplacement modes discussed in Section 8.5.2. The first layout, designated Option I, uses the same layout concepts originally developed as a part of ESF/Repository interface work in FY 1993 and 1994 (M&O, 1993b; M&O, 1994a), with refinements in certain areas to enhance operational aspects and to conform to a new geologic model that contains later drilling information. The Option I layout incorporated the design objectives listed in Section 8.6.1 and is discussed briefly in Section 8.6.3, followed by more thorough descriptions in later report sections. The second, designated Option II, is an alternative to the Option I layout that provides a different method for developing a repository using TBMs, including a means for developing larger diameter emplacement drifts and a configuration that might have significantly different radiological safety aspects than the Option I layout. The Option II layout is discussed in Section 8.6.2.1.

8.6.2.1 Conceptual Repository Layout - Option II

An Option II layout concept, which is a variation primarily in the method in which emplacement drifts are configured, was developed in FY 1994. One "panel" of emplacement drifts illustrating the concept is shown in the left side of Figure 8.6.2-1. Other aspects of this figure are discussed later in this section. A complete repository layout using the Option II configuration has not been developed to-date; however, in Figure 8.6.2-1, a typical "panel" consisting, for example, of nine emplacement drifts is shown. Fewer drifts could be excavated in a panel if desired, but it is felt that nine drifts are close to a practical maximum



NOTE: ALL DIMENSIONS, CURVE RADII, AND STANDOFF DISTANCES SHOWN FOR ILLUSTRATIVE PURPOSES ONLY.

Figure 8.6.2-1

ALTERNATE LAYOUT
GENERAL DEVELOPMENT PLAN

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regan /proj/repas/mine/dgn/ssrm-sk122.dg limit, primarily due to the resulting loss of disposal area. This is because the innermost emplacement drifts move further into the emplacement area as the number of drifts in the panel increases.

The basic configuration shows, for example only, emplacement drifts spaced at 40 m centers and curves within the emplacement drifts at a 100 m radius. In an actual layout, the drift spacing would be established based upon thermal loading and other requirements. The emplacement drift curve radii would be established by the curve performance limitations on the TBM. Curve performance limitations are based upon many factors, many of which are particular to a TBM manufacturer's design or machine set up. Factors include the size of the opening, length of the machine, internal construction within the TBM (such as length of the main beam or ability to articulate), length from the cutting head face to the cutting head pivot point, and the design of the muck handling components within the trailing gear (such as length or segmental design of the bridge conveyor).

The Option II concept uses the same perimeter boundary (i.e., the perimeter and service main drifts shown in Figure 8.6.3-1) as the Option I concept. Because of this, a number of the key design objectives associated with the Option I are also met in the Option II concept. Significant differences between the two concepts are discussed, and compared in general terms, below.

A. Utilize an In-Small Drift Emplacement Concept - The Option II layout can be used with either of the proposed emplacement configurations outlined in Section 8.5.2. However, because of differences in TBM launching concepts, the Option II layout is not restricted to small diameter emplacement drifts, because it does not rely on a mechanized approach for TBM launching as in the Option I layout. Due to the emplacement drift entry differences and curves located in those drifts, some design differences in emplacement and backfill equipment would be required compared to the Option I layout.

B. Use Conventional Rail Transportation for Both Emplacement and Development Operations - Curve radii within the Option II concept emplacement drifts, while smaller than those used in the Option I layout, are judged to be suitable for rail operations throughout.

C. Minimize the Number of Main and Secondary Access Drifts - The Option II layout uses the same service main and perimeter main drifts, as well as shaft and ramp configuration as the Option I layout. A TBM Launch/Waste Handling Main, used in the Option I layout and discussed in greater detail in Section 8.6.4.4 is not incorporated into the Option II layout. The amount of secondary access drifting is generally comparable between the two concepts. For example, main drift crosscuts in the Option I layout are replaced by access crosscuts into the panel in the Option II concept.

D. Maintain Straight Emplacement Drifts - Design features discussed below that are associated with the Option II layout dictate that curves in portions of the emplacement drifts are required; therefore, straight emplacement drifts are not maintained.

The second purpose of the Option II was to develop a configuration that would offer significantly different approaches to several key aspects associated with the Option I layout. The different approaches are summarized below. As with any concept, some features may be more or less desirable, depending upon viewpoint and the degree of importance placed upon a particular feature. Presentation of such differences may eventually be useful to serve as a vehicle to reinforce the final selection of one particular concept over another.

Concept for Launching TBMs - A key aspect in developing any realistic layout concept which assumes TBM development as the primary excavation tool (M&O, 1994m, DCSS-005) is a method of developing the many emplacement drifts without excessive TBM launching costs. In general, costs for launching are incurred in varying degrees: 1) when a TBM must be repeatedly disassembled and reassembled, 2) when a TBM must be moved frequently over long distances, unless a mechanized approach is available to move the machine more or less intact, and 3) when extensive excavations are required to launch a TBM each time.

The Option II layout uses an approach in which TBM launches are minimized to the extent possible, which is a function of the spacing of the emplacement drifts and the curve radii within the emplacement drifts. For the spacings (40 m) and radii (100 m) shown in Figure 8.6.2-1, nine emplacement drifts can be excavated with only six launches, if desired. For comparison, with a nine drift panel, if the curve radii were held at 100 m but the drift spacings were reduced to 20 m, nine emplacement drifts would require nine launches. If the curve radii were reduced to 40 m (requiring a non-conventional TBM not produced by most major manufacturers) and the drift spacing was 20 m, two launches would be required, and so on. In other words the number of launches increases as the spacing decreases for a fixed radius or as the radius increases for a fixed spacing.

In the Option II concept, the movement of the TBM between launch points is minimized while developing a panel. As stated earlier, the nine drifts shown in Figure 8.6.2-1 comprise one panel. Once a TBM breaks through into the access cross cuts at the center of the panel, the machine is moved forward only a relatively short distance (the move requires some rotation of the TBM to align with the new launch point), as discussed later in this section. TBM moves between panels will require some disassembly and reassembly to occur.

The Option II concept requires separate excavations for TBM launches, compared to the mechanized launch tube concept described in Section 8.7.1 for the Option I layout. These excavations are generally included as a part of the emplacement drifts to minimize their cost impact.

Using the basic Option I premises for thermal loading and emplacement drift spacing (Items N and U in Section 8.6.1), the Option II layout geometry, which is configured to some extent to facilitate TBM launching, has several ramifications which are disadvantages inherent in the Option II concept.

The first ramification is that, although the Option II concept can meet both the high and low thermal loading scenarios (Item N), it may not, as configured in Figure 8.6.2-1, utilize the available disposal area as efficiently as the Option I concept; comparison calculations have not been performed to determine the extent. A potential reason for this is because the total standoff from the center of the service and perimeter mains to the emplaced WPs is 150 m in the Option II configuration (refer to Figure 8.6.2-3, which is discussed later in this section). As a comparison, the Option I concept uses approximately 119 m of total standoff. Some additional disposal area is also lost due to the center access drift leading into each panel which will require WP standoffs in each emplacement drift which connects to it. The extra length added due to the curves of the emplacement drifts may reduce the impact of the above features somewhat.

The second ramification is that to incorporate the 22.5 m drift spacing philosophy of the Option I concept (Item U) would require either nine TBM launches if 100 m emplacement drift curve radii were maintained, or the curve radii could be reduced to 40 m which would require only two launches in a nine drift panel. The ramifications of the first approach are that a higher launching cost would result, but a relatively conventional TBM design could be used to excavate the emplacement drifts with 100 m radius curves. The ramifications of the second approach are that launching costs would be reduced, but a non-conventional TBM design, as mentioned earlier, would be required to excavate the emplacement drifts with 40 m radius curves.

The Option I layout premise regarding favorable drift orientation (Item Z in Section 8.6.1) is generally met by Option II emplacement drifts for the majority of their length, but the curved portion of the emplacement drifts would not fall within a favorable orientation window (Figure 5.1.6-1). A secondary window, which could potentially be considered favorable by examination of Figure 5.1.6-1, brackets an average orientation of approximately N 10 W. Some portions of the emplacement drifts connecting into the center access drifts would meet this secondary potentially favorable orientation.

Sequence for Emplacement Drift Development - Development begins first by excavation of the service and perimeter main drifts. After the perimeter and service mains are excavated, panel development can begin. The left side of Figure 8.6.2-1 shows launch points for the TBM, as discussed above, as well as the overall sequence of emplacement drift development (numbers 1 thorough 9) in each "panel".

Prior to the emplacement drift development in a panel, the chamber for the initial TBM launch into the panel, and the center access crosscuts are excavated by techniques such as a roadheader. The center cross cuts are both stopped short of their intersection with the outer emplacement drift, as represented in Figure 8.6.2-1, Early Stage Development". This allows the option for continuous emplacement drift TBM excavation without a launch, until the full 90° curve of the emplacement drift can no longer be excavated because of TBM curve performance limitations.

As discussed earlier, this example assumes a 100 m minimum curve radius as the performance limitation, which allows the first four emplacement drifts to be excavated using a single launch. The "Later Stage Development" portion of Figure 8.6.2-1 shows the point where the fourth drift is nearing completion. At completion, the TBM breaks into the center access crosscut and is moved into the second launch point (The first being the initial launch into the emplacement panel) which has been developed ahead of that time. Five successive breakthroughs and launches occur in a similar manner as each emplacement drift is excavated until the final breakthrough of the center emplacement drift occurs into the end of the cross cut. At this point, the TBM is disassembled as required based upon opening sizes and travel clearances and moved to the next nine drift panel.

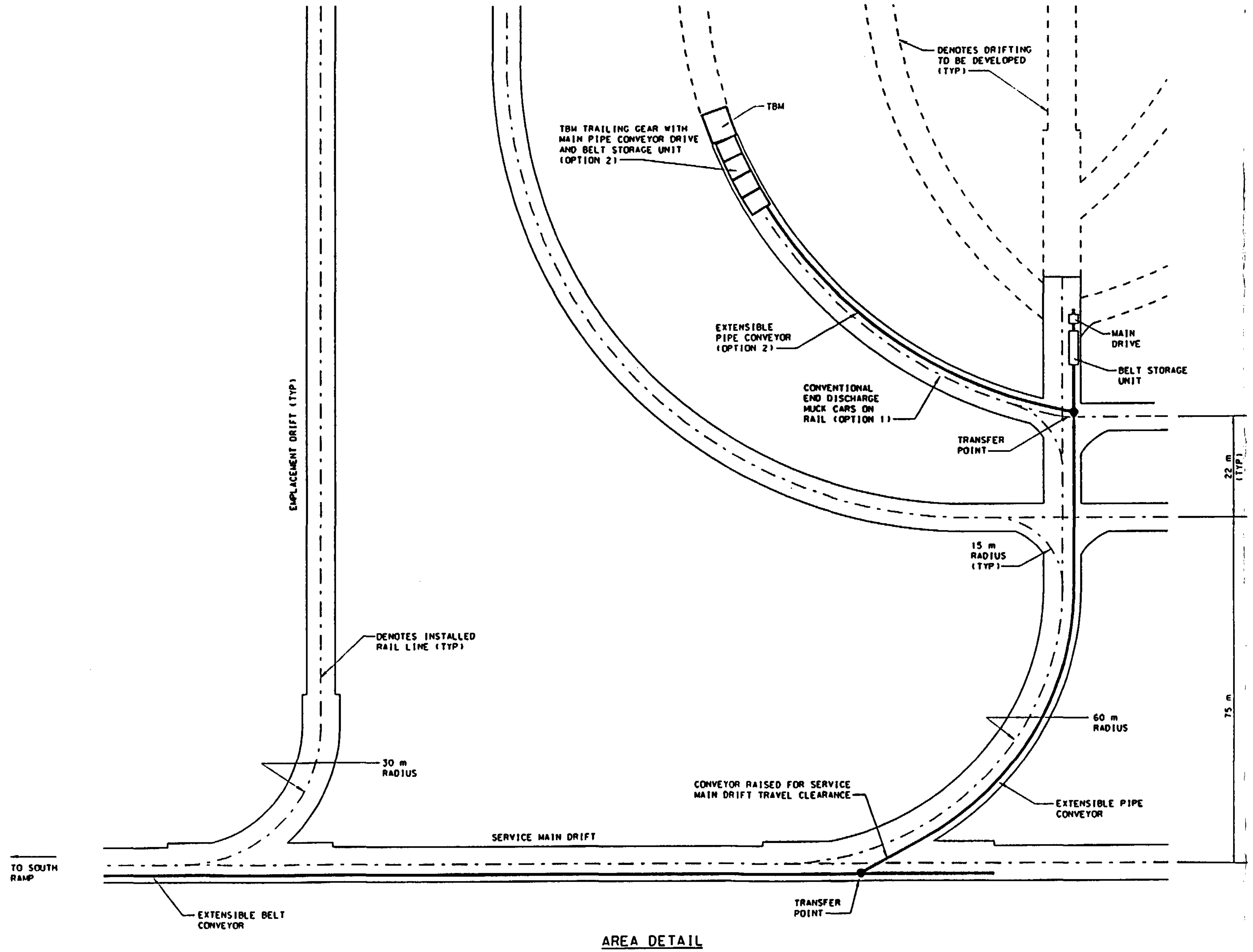
The development of the access crosscuts and launch chambers on each side of the panel requires careful integration of those activities with emplacement drift TBM excavation, muck handling, and supplies transportation operations. The general principle for development of the center access crosscuts is that they are advanced in stages as the emplacement drifts in the emplacement panel are completed. In general, using Figure 8.6.2-1 for reference, if the emplacement drift is being advanced toward the service main side of the panel, the center access crosscut on the service main side is being advanced. This advance includes short emplacement drift stubs for the TBM to break into, as well as excavation of that portion of the following emplacement drift that will serve as the next launch chamber. Examples of these excavations are shown on the service main side in the "Later Stage Development" portion of Figure 8.6.2-1.

Exceptions to this general development sequence are when the TBM is excavating the "first loops" of the emplacement panel spiral. Using the configuration shown in Figure 8.6.2-1, the "first loops" would consist of the first four drifts that are developed after the first launch but before the second launch. In this stage of panel development, access crosscut development would occur opposite the direction of TBM advance (i.e. crosscut development on the perimeter main side when the TBM is heading toward the service main side). An example of when this advance would be necessary is shown on the perimeter main side of the panel in the "Early Stage Development" portion of Figure 8.6.2-1.

From a practical standpoint, to carry out an excavation operation as described will require some flexibility in the scheduling of personnel and will require worker skill versatility. Crosscut excavation operations could be scheduled during shutdowns such as a weekend, with the crosscut advanced as far as possible during the shutdown period. Alternately, emplacement drift excavation operations could be temporarily suspended for several shifts while the crosscut is advanced using the TBM crew to accomplish the conventional excavation operations. This type of scheduling and worker flexibility is common in underground mining operations.

The Option II concept allows the capability to conduct simultaneous development and emplacement operations; although, two full emplacement panels would need to be completed prior to the start of emplacement operations. One panel would be available and used for emplacement. The second panel would have finish construction operations being conducted such as invert and shielding door construction. A third panel would then be under excavation at that time.

Muck Handling Options - A current assumption in the CDA is to use conveyors for muck handling where practical (M&O, 1994m, DCSS-010). The Option II concept is configured to allow the flexibility to use a mix of conventional and specialty conveyors to accomplish this. Figure 8.6.2-2 provides a general plan for muck haulage with the Option II concept. As shown in that figure, an extensible troughed belt conveyor (M&O, 1993d, p. 5-17 to 5-20) is located in the service main drift. This conveyor handles muck from a portion of the panel



NOTE: ALL DIMENSIONS, CURVE RADII, AND STANDOFF DISTANCES SHOWN FOR ILLUSTRATIVE PURPOSES ONLY.

Figure 8.6.2-2

ALTERNATE LAYOUT SHOWING MUCK HANDLING CONFIGURATION

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development and continues up the South Ramp to the surface. A similar extensible conveyor would be installed in the perimeter main drift.

Within the panel, located in the center access crosscut, is a pipe conveyor (M&O, 1993d, 5-14 to 5-17) equipped to operate as an extensible belt system, as shown in Figure 8.6.2-2. A pipe conveyor is a specialty system seeing growing emergence in industrial applications as an alternative to conventional troughed belt conveyors. It would be capable of negotiating the majority of the curves designed into the Option II. At the loading point, a pipe conveyor is open in a conventional trough form, after which, it is formed into a pipe shape for the transport length with the material being handled completely enclosed. At the end of the transport run, and just before the discharge pulley, the belt again opens, thus allowing materials to be discharged in a normal fashion. The belt again forms into a pipe for the complete return run. A pipe conveyor with an extensible belt system was studied and was considered to be a feasible alternative to the conventional belt system that was installed on the recent Boston Harbor TBM tunnel project (M&O, 1993u).

As the crosscut is advanced into the panel, the pipe conveyor tail, magazine sections, and transfer point would be moved in as required. Modular design of such components would enhance the capability to perform this activity. An identical, extensible pipe conveyor would also be installed in the access crosscut in the perimeter main side of the panel.

In some cases the configuration of a layout, particularly the inclusion of small-radius curves, and the size of the openings, make the use of a conveyor impractical in certain areas. An example of such a case is where, in a layout similar to Option I, the use of conveyors for muck handling was judged to be impractical (M&O, 1993d, p. 5-44). Rail car muck haulage is used in the Option I concept for emplacement drift muck haulage as (discussed further in Section 8.7.1.2).

The Option II concept allows the use of either rail car muck haulage or an extensible pipe conveyor system, as discussed above, in the emplacement drifts. An example of these options is shown in Figure 8.6.2-2. If rail haulage was used, end discharge type muck cars (M&O, 1993d, p. 5-26) would be the most practical way of loading directly onto the pipe conveyor in the center access crosscuts.

A key feature of the Option II layout is that muck haulage and supplies transportation (as shown in Figure 8.6.2-1) alternates between the perimeter and service main sides of the panel through the center access crosscut. For example, when the TBM is advancing toward the perimeter main side of the panel, muck and supplies are transported out of the panel on the service main side, and vice versa. An exception to this is when the first emplacement drift in the panel is being excavated. The muck and supplies route is shown in this case under "Early Stage Development" in Figure 8.6.2-1. For this first drift, muck haulage could be by rail using the configuration of the first launch point shown in Figure 8.6.2-1. If an extensible pipe conveyor was used, the curve in the first drift launch chamber is too small for operation of this type of belt system, as drawn in Figure 8.6.2-2. To accommodate such a belt, the curve at the first launch point would need to reflect those shown for the center access crosscuts. An approach may be to use rail haulage for the first drift and pipe conveyor haulage for the remaining emplacement drifts, but flexibility for this would need to be designed into the trailing sections of the TBM.

Radiation Environment at the Emplacement Drift Entrances - The Option II concept is configured in a manner such that the radiation sources in most emplacement drifts can be isolated by a combination of several methods. Three methods are used to isolate the source: engineered shielding, distance, and engineered and natural barriers. Engineered barriers include things like corners or minimized direct line of site. Natural barriers include the rock pillars in the emplacement area. Features incorporated into the Option II concept that would potentially mitigate radiation exposure using the above three methods are shown in Figure 8.6.2-3.

To achieve a greater assurance of radiation safety, the trade-off may result in a higher constructed repository cost and somewhat less efficient use of available disposal area to achieve these or other similar types of radiation mitigating features. This trade-off requires very comprehensive evaluations, not included in work scopes to date. If the above described or other engineered features could successfully control radiation levels at the waste handling drift to within acceptable limits, it may be possible to have controlled but relatively unrestricted human access in drifts adjacent to the emplacement drifts as a part of normal emplacement side operations.

8.6.3 Interim Layout Configuration

An objective comparison of all aspects of the Options I or II layouts has not been made at this time. Comprehensive personnel radiological safety and/or waste isolation performance evaluations of either layout, as well as representative cost comparisons, have not yet been conducted. In addition, many design aspects of the Option II layout have not been developed to the same level of detail or refinement as for the Option I layout. Work of this nature will be performed to define needed details, and the strengths and weaknesses for each of these layouts, as well as any additional layout configurations that may be developed as ACD progresses, will eventually be evaluated.

Lacking this additional work, and because it is felt that the Option I layout has been sufficiently refined to establish it as a workable concept that maintains linkage with current ESF design, the Option I layout shown on Figure 8.6.3-1 is used as the representative case under the terminology "Interim Layout," and is used as the basis for various discussions and descriptions presented subsequently in this report. A description of the major openings associated with the interim layout are presented in Section 8.6.4, followed by discussions of operational concepts and other features in later report sections.

8.6.4 Interim Layout Description

8.6.4.1 North Ramp

The North Ramp's initial function will be to provide first time access to the repository horizon to support site characterization activities. It may also be used as a launch point for exploratory drifting access to the underlying Calico Hills unit.

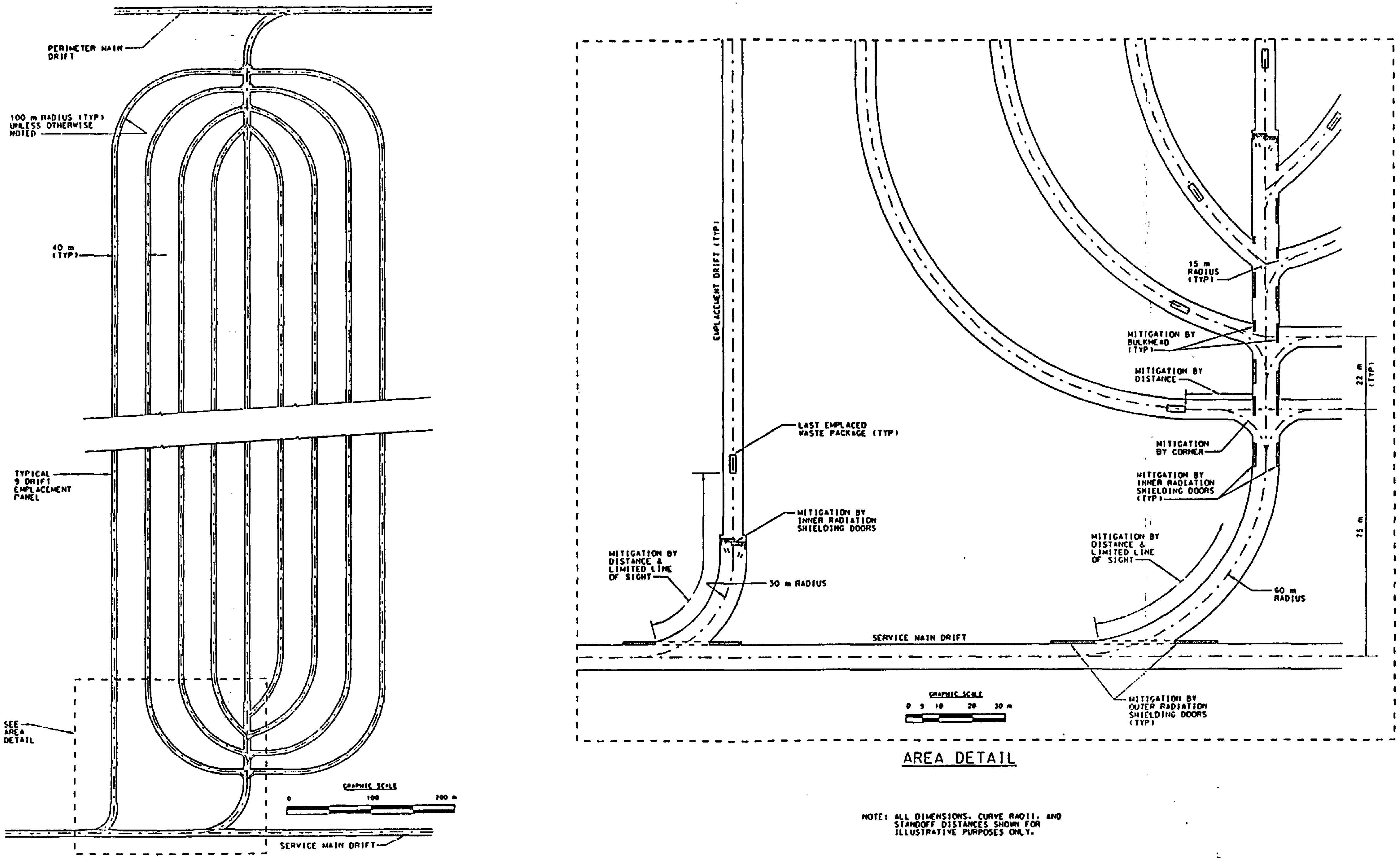

Figure 8.6.2-3

Alternate Layout Using Features Which Potentially Mitigate Radiation Exposure

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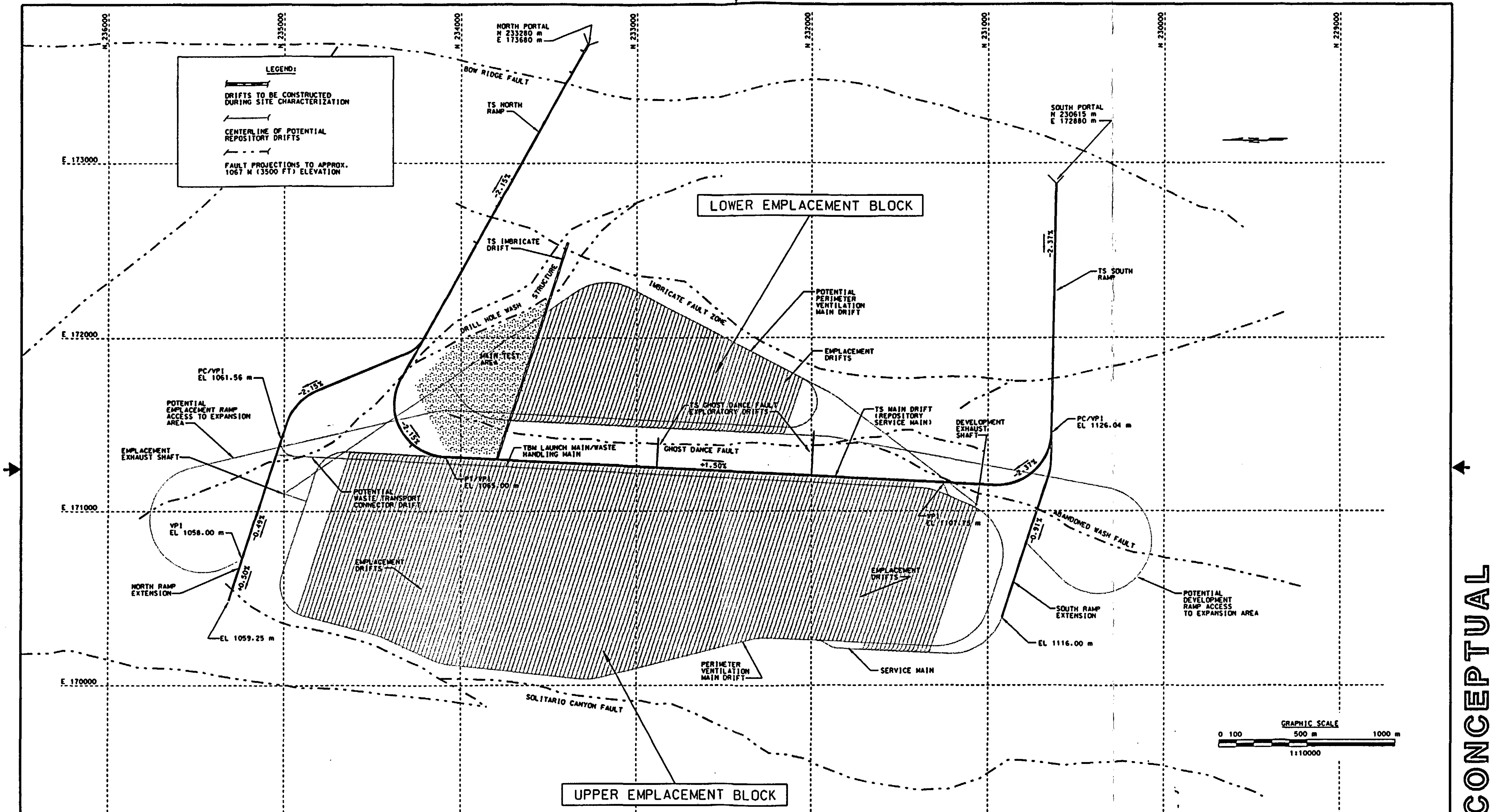

FIGURE 8.6.3-1
INTERIM ESF/REPOSITORY CONCEPTUAL LAYOUT, OPTION 1
(WITHOUT CALICO HILLS DRIFTING)

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The ramp will be 7.62 m in diameter. The location of the North Ramp Portal and the alignment and diameter of the ramp were fixed during ESF Title II design (YMP, 1994b). A starter tunnel for launching a 7.62 m diameter TBM has been constructed.

In the interim repository layout, the North Ramp serves as the primary access for transportation of WPs to the subsurface from the waste handling building. The North Ramp also serves as the primary corridor for the transportation of personnel, equipment, and materials to support emplacement operations and serves as the primary intake airway for the emplacement side.

The gradient of this ramp was minus 8.9 percent in the SCP-CDR (SNL, 1987a). Later geologic interpretations that raised the TSw1/TSw2 contact in the northern portion of the primary area allowed the gradient to be decreased to minus 6.9 percent during ESF Title I design. The gradient of the North Ramp in the layout shown on Figure 8.6.3-1 is minus 2.15 percent (M&O, 1994p), beginning at a point just inside the starter tunnel, extending through the curve that leads into the service main, and ending at the intersection of the curve with the service main.

The North Ramp could be configured for repository emplacement operations as shown in the general cross section on Figure 8.6.4-1. Utilities installed in the ramp and shown in that figure are discussed in Section 8.10.3. The ramp includes two rail lines with one electrical trolley. The purpose of the inner rail line is to provide a rail corridor for the locomotive that serves as the prime mover for the WP transport cask carrier.

The transport cask carrier will be a relatively simple railcar used to carry the cask from the waste handling building to an emplacement platform situated at the entrance to an emplacement drift. The carrier will require a relatively wide wheel base for lateral stability because of the wide, heavy load of the transport cask with contained WP. The outer two tracks are therefore included to provide a wide running base for the carrier.

A single trolley is used as the ramp should not receive high personnel and materials transportation traffic during emplacement operations. In addition, from a safety standpoint, it would probably not be desirable to have two-way traffic in the ramp while transporting a WP to the subsurface. Thus, the ramp will require controlled access as described in Section 8.7.2.1, and potentially, signaling systems may be necessary to enhance ramp operational safety.

8.6.4.2 North Ramp Extension

The North Ramp extension will be excavated during the site characterization phase of the YMP program. Its initial function is to provide an east-west crossing of the potential repository block to explore for north-south trending geologic features and to examine the Solitario Canyon Fault. It can also be used for access to test alcoves or drifts that could be located in the upper half of the TSw2 unit along the lower reaches of the alignment.

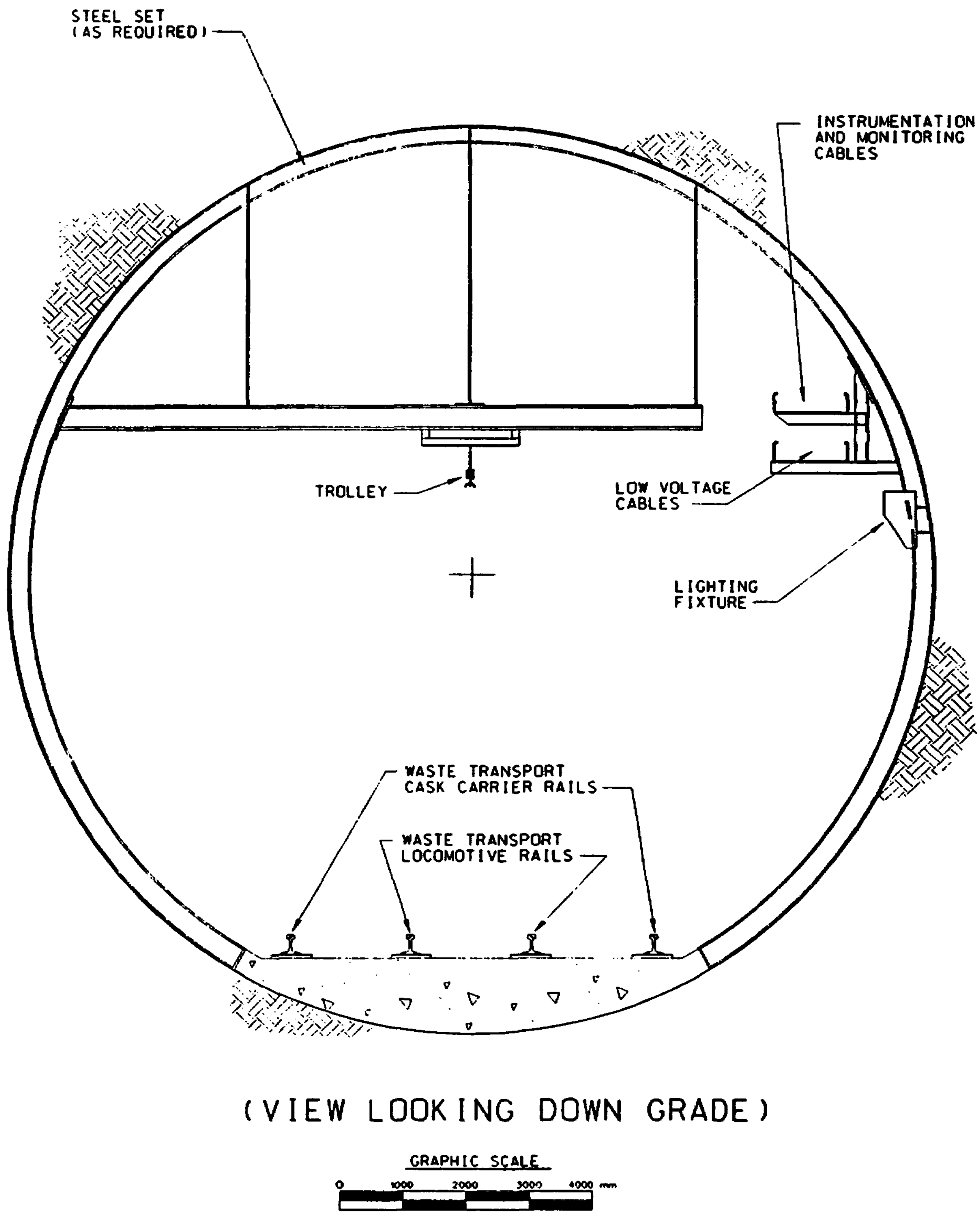


Figure 8.6.4-1. North Ramp Cross Section (During Emplacement Operations)

The configuration of the North Ramp extension as shown on Figure 8.6.3-1 differs significantly from that shown on Figure 8.1-7, which represents the current baseline for this opening. The changes in alignment were made to enhance the utility of this opening in the potential repository by providing an alternate means of accessing the waste handling main for WP transport and to provide repository construction access for this main via the potential waste transport connector drift indicated on Figure 8.6.3-1. The reconfiguration also permitted the repository emplacement area to be extended further north, increasing the area available for emplacement, and partially offsetting area lost in the southwest corner of the emplacement block as discussed in section 8.6.4.5. The realignment is also beneficial to the site characterization effort for the following reasons:

A. The intersection formed between the North Ramp and the turnout for this drift as currently baselined (Figure 8.1-7) was located at the approximate point where the Drill Hole Wash Structure is predicted to cross the North Ramp alignment. The reconfiguration moves the turnout farther east in an attempt to avoid potentially difficult ground conditions at the intersection. Because of difficulties associated with accurately predicting the location of the Drill Hole Wash Structure, the proposed location of this turnout will have to be field verified during construction.

B. The close proximity of the North Ramp extension to the repository perimeter main, as currently baselined has potential test/repository interferences, and therefore does not provide a great deal of flexibility with respect to potential test alcoves or drifts that might be located off the extension. The realignment moves the extension further away from the perimeter main and should provide more flexibility regarding the layout of test alcoves and/or drifts.

C. The point where the North Ramp extension crosses the Solitario Canyon Fault was not changed, but the azimuth used in the longer leg of the realignment to access that point was set the same as shown on Figure 8.6.3-1 for the potential emplacement drifts (288 degrees). This may be advantageous in terms of correlation between testing data and potential repository design.

D. The realignment avoids potentially difficult tunneling conditions that could have been experienced using the current alignment. The baselined alignment shown on Figure 8.1-7 runs in close proximity and sub-parallel to the Drill Hole Wash Structure along much of its length. The proposed realignment avoids this condition, but does cross the Structure at a high angle about midway along the reach. Combined with the crossing of the Drill Hole Wash Structure that will be made in the lower portion of the North Ramp, the second crossing facilitated by the realignment will provide better understanding of this structure in the immediate area and should help define limits for repository openings in nearby areas.

Based on cross-sections generated by the Lynx geologic model as described in M&O (1994s), the realignment would traverse about the same horizontal distance within the TSw2 as the baselined configuration, but will expose slightly more of the unit because the alignment terminates at a lower point in the stratigraphic column.

A negative feature of the realignment is that the total length of the North Ramp extension would increase by approximately 408 m relative to the current baseline configuration. However, this increase is offset by a 828 m decrease in the length of the South Ramp extension (see Section 8.6.4.8), resulting in a net 420 m decrease in the combined lengths of these two drifts.

Figure 8.6.4-2 is a section showing the position of the North Ramp and the extension relative to geological and other surfaces generated by the Lynx computer model.

During repository operations, this ramp extension could provide access to a centrally located, dedicated waste emplacement main, if such is determined to be necessary based on retrieval, backfilling or other concerns. If lower thermal loadings or other conditions result in a need to develop emplacement areas on the east side of the Ghost Dance Fault, then this extension would provide a launch point for driving an emplacement operations access ramp to the lower block. (An emplacement block located east of the primary block would be significantly lower in elevation due to the eastward dip of the formation.)

The diameter of the extension would be 7.62 meters, consistent with other openings that serve as primary accesses and airways in the integrated layout.

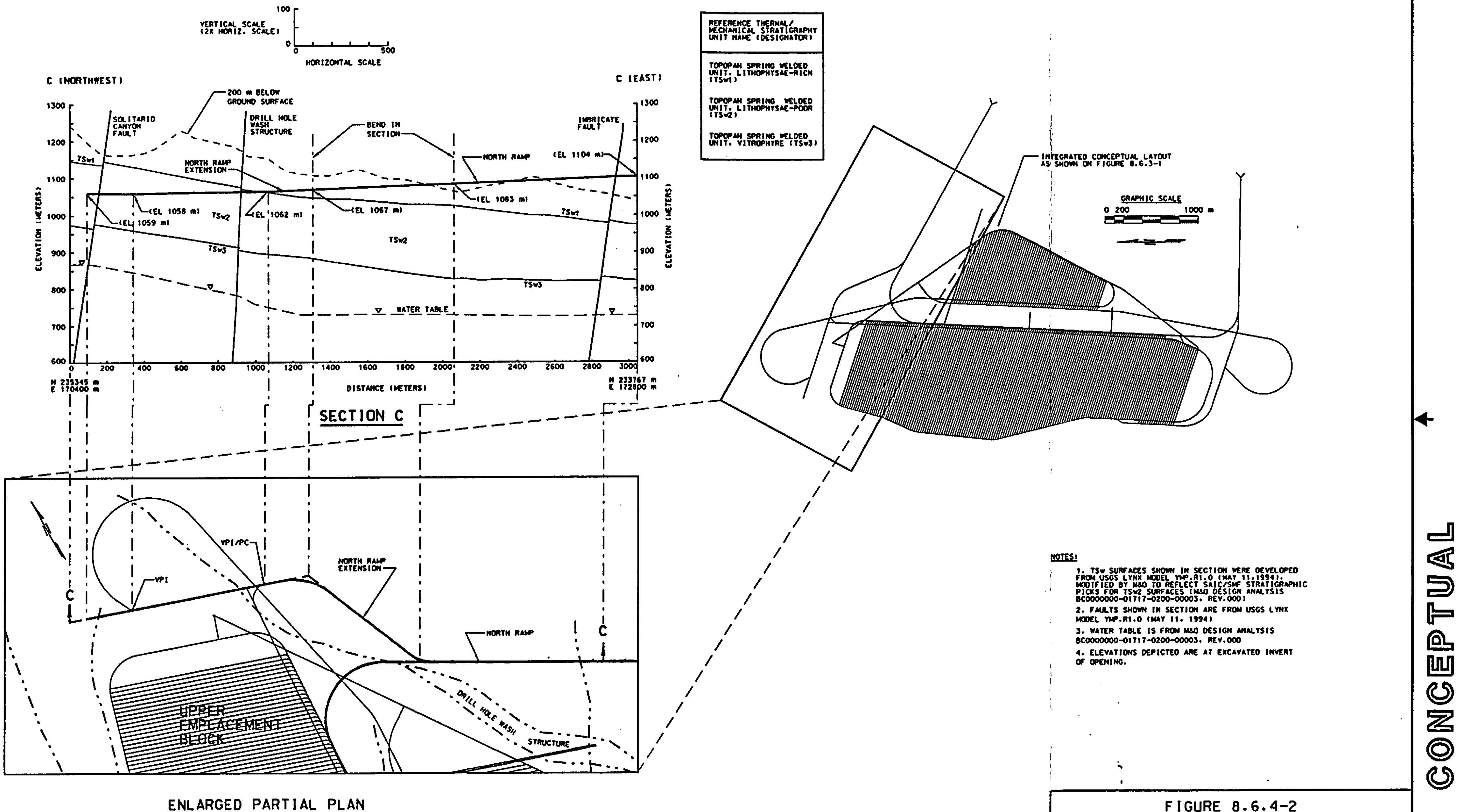
8.6.4.3 Service Main

Except for a short reach extending north from the intersection with the bottom of the North Ramp, the remainder of the service main would be excavated during site characterization where it is called the "TS Main Drift" or the "North-South Drift."

This opening is the primary feature in the integrated layout that controls the gradient of all other main drifts and of the North and South Ramps. It also controls the elevation of the emplacement drifts.

One of the key assumptions listed in the CDA (M&O, 1994m, Key 023) is to avoid emplacement drifts crossing major faults such as the Ghost Dance Fault. Since the larger area available for emplacement is west of the Ghost Dance Fault, this led to a basic design decision to locate the service main west of, and to orient the service main more or less parallel to, the Ghost Dance Fault. Because very little is known about the character of the Ghost Dance Fault at depth, and because it is doubtful that much additional information will become available prior to excavation of the service main during site characterization, it was decided that a minimum 120 meter standoff distance should be allowed between the drift and a projection of the main surface trace of the fault to the repository horizon.

The dip of the Topopah Spring Unit is basically to the east. Therefore, in order to accommodate the design assumption/objective dealing with flat-lying emplacement drifts, it was necessary to situate the service main high in the TSw2 in order to provide for maximum utilization of the unit when horizontal emplacement drifts are extended to the west.



NOTES:

1. TSw SURFACES SHOWN IN SECTION WERE DEVELOPED FROM USGS LYNX MODEL YMP.R1.0 (MAY 11,1994). MODIFIED BY M&O TO REFLECT SAIC/SMF STRATIGRAPHIC PICKS FOR TSw2 SURFACES (M&O DESIGN ANALYSIS BC0000000-01717-0200-00003, REV.000)
2. FAULTS SHOWN IN SECTION ARE FROM USGS LYNX MODEL YMP.R1.0 (MAY 11, 1994)
3. WATER TABLE IS FROM M&O DESIGN ANALYSIS BC0000000-01717-0200-00003, REV.000
4. ELEVATIONS DEPICTED ARE AT EXCAVATED INVERT OF OPENING.

FIGURE 8.6.4-2
SECTION SHOWING STRATIGRAPHY ALONG NORTH RAMP AND EXTENSION

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As shown on Figure 8.6.4-3, the service main slopes upward to the south at 1.50 percent to the bottom of the South Ramp. Based on the structure contour map presented as Figure 5.1.2-3 in Section 5.1.2, the crown of the service main is located immediately below the TSw1/TSw2 stratigraphic contact at the north end of the layout, and is approximately 37 meters below this contact at the bottom of the South Ramp.

The alignment and grade of the service main as shown on Figure 8.6.3-1 and 8.6.4-3 have been revised from that shown in the baselined ESF/Repository interface drawings (M&O, 1994o). Consistent with a comment made by the repository subsurface design group during the 90 percent review of ESF Design Package 2C, the alignment of the TS Main Drift/Repository Service Main has been straightened, eliminating the slight bend located at the approximate mid-point, in order to enhance and simplify various operational aspects relating to repository development and emplacement processes--primarily those dealing with service and TBM launching equipment and waste emplacement equipment. Based on similar reasoning and using the structure contours defined by the current Lynx geologic model (see Figure 5.1.2-3), the grade break in the main drift (from 0.5 percent to 2.0 percent) has been eliminated; a constant grade of 1.50 percent is now used.

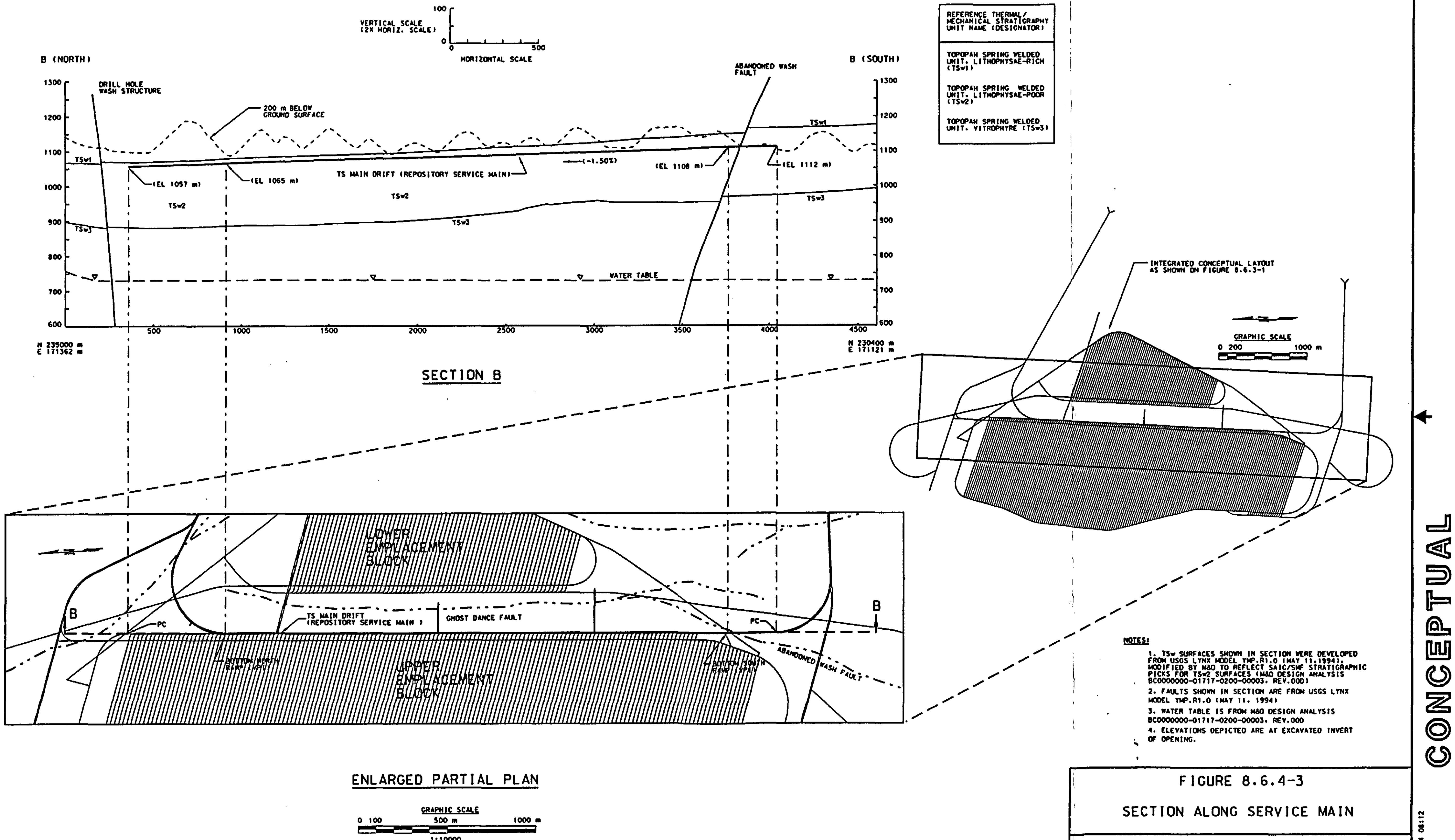
During repository operations, the service main would function as the primary, on-block accessway for development operations personnel, equipment, and materials haulage, and would provide space for utilities installation and a conveyor system for transporting excavated tuff away from the active emplacement drift development area. It would accommodate a movable, raised platform upon which numerous rail switching tracks and crossovers would be mounted to facilitate simultaneous access into several different emplacement drifts in varying stages of construction.

In the southern portion of the upper emplacement block, a short section of service main is located in the southwest corner of the potential emplacement block. This feature of the layout was necessitated by a need to begin a climb in the eastern side service main away from the southeast corner of the emplacement area in order to minimize the grade of the South Ramp and maintain a gradient under 2 percent in the service main. An equally importance consideration was to avoid an area of less than 200 m cover in the southeastern corner. In this section of the upper emplacement bock, the operational functions of the TBM launch main and the ventilation perimeter main would reverse. That is when emplacement drifts are developed in this area of the upper block, the emplacement drift TBMs would traverse the block from west to east as opposed to the normal each to west direction.

The service main would also function as a primary ventilation airway in both emplacement and development operations.

8.6.4.4 TBM Launch Main/Waste Handling Main

The TBM Launch Main/Waste Handling Main is oriented parallel to the service main and the two are interconnected by crosscuts at each emplacement drift location. This opening would be constructed during the initial phase of repository construction, prior to emplacement of waste. It would be 9.0 meters in diameter, an increase from the 7.62 meter diameter mentioned in M&O, 1993b and M&O, 1994a. This change was necessitated by the greater



NOTES:

1. TSw SURFACES SHOWN IN SECTION WERE DEVELOPED FROM USGS LYNX MODEL YMP.R1.0 (MAY 11,1994), MODIFIED BY M&O TO REFLECT SAIC/SMF STRATIGRAPHIC PICKS FOR TSw2 SURFACES (M&O DESIGN ANALYSIS BC0000000-01717-0200-00003, REV.000)
2. FAULTS SHOWN IN SECTION ARE FROM USGS LYNX MODEL YMP.R1.0 (MAY 11, 1994)
3. WATER TABLE IS FROM M&O DESIGN ANALYSIS BC0000000-01717-0200-00003, REV.000
4. ELEVATIONS DEPICTED ARE AT EXCAVATED INVERT OF OPENING.

FIGURE 8.6.4-3

SECTION ALONG SERVICE MAIN

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length MPC-based WPs relative to the multibarrier package concept (5.6 meters versus 5.0 meters) and adoption of 5.0 meter diameter emplacement drifts in lieu of the 4.3 meter diameter drifts used in the previous work.

The function of this main in development operations, as implied by its name, would be to provide space for mechanized launching (see Section 8.7.1.1) of a 5.0 meter diameter TBM for excavation of emplacement drifts. Launching eliminates the need to construct individual launch chambers at each emplacement drift location. It is conceivable that the service main could provide this function, thereby eliminating the need for construction of an additional large diameter opening. However, it is highly probable that more than one TBM will be required in order to maintain a sufficient rate of emplacement drift construction to support the waste receipt schedule. Without a dedicated launch main, it would be extremely difficult to launch one TBM while servicing another from the same primary access opening due to interference between the two operations.

In emplacement operations, this main would serve as the primary, on-block waste handling drift on the emplacement side of the repository. Its diameter would be sufficient to permit rotation of the WP subsurface transport cask (in a horizontal plane) to align the WP with an emplacement drift opening.

This opening would also serve as a primary ventilation airway for both development and emplacement operations.

8.6.4.5 Perimeter Ventilation Main

The perimeter ventilation main functions as a primary ventilation airway in both development and emplacement operations. It would be 9.0 meters in diameter and would be excavated during the initial stages of repository construction, prior to waste emplacement. As with the launch main, the diameter of this drift has been increased relative to that described in previous work (M&O, 1993b and 1994a) to facilitate handling of the MPC-based WPs and the 5.0 meter diameter emplacement drift TBMs.

In addition to providing ventilation, this main also affords an alternate means of access to the emplacement drifts for carrying out instrumentation monitoring, performance confirmation, or similar tasks that might interfere with actual emplacement activities being conducted in the waste handling main. It would also serve as a backup means of access to retrieve or extract WPs in the unlikely event of a rock fall or other off-normal condition that might occur in an emplacement drift. During emplacement drift backfilling operations (if backfilling is determined to be necessary), this opening would be utilized extensively as a means of delivering backfill to the western half of the emplacement drifts, thereby reducing the distance that backfill conveyance devices inside the emplacement drifts would be required to deliver the backfill material.

On the development side of the repository, this opening provides space for specialized equipment to retrieve the smaller diameter emplacement drift TBMs as they complete each drive across the block. The perimeter main also provides a route for the TBMs to be transported back to the east side (except as noted in Section 8.6.4.3) of the repository, into the launch main, to begin another emplacement drift.

The location of this drift is determined by physical conditions of the site. Along much of the northern half of the alignment, its location in plan was established by allowing for a 60 meter standoff from the Solitario Canyon Fault (M&O, 1994m, Key 023). Toward the south end, however, it was necessary to limit westward extension of emplacement drifts in order to maintain at least 30 meters standoff between WPs along the edge of the thermal buffer zone adjacent to this opening and the TSw2/TSw3 contact. The structure contours generated by the Lynx geologic model (refer to Figure 5.1.2-4) show this contact at a significantly higher elevation in this area when compared to the IGIS model that was used as the basis for locating this drift in M&O, 1993b and M&O, 1994a. The effect of this change is a reduction in available emplacement area.

Since flat-lying emplacement drifts are at the same elevation where they intersect the perimeter main as they are at the east end where they join with the launch main, and since grades in the launch main parallel those in the service main (the basis for elevations in the service main was discussed in Section 8.6.4.3), grade control in the perimeter main is determined by elevations in the service main throughout the emplacement area. At the south end of the layout, the perimeter main would slope up to a high point to facilitate drainage. At the north end, the perimeter main would slope downward to a collection sump located at the emplacement operations ventilation shaft. Section 8.9 discusses repository drainage in greater detail.

The curved portions of the perimeter main at the north and south ends of the repository block are configured to provide for ease of constructibility through the use of long radius curves. At the south end of the block, the main is situated to avoid increased faulting and areas where the 200 meter cover restriction becomes limiting. At the north end of the layout, it is located just south of the Drill Hole Wash Structure at the point where the main curves to meet the service main.

8.6.4.6 Waste Emplacement Drifts

The diameter of waste emplacement drifts in the interim layout is 5.0 meters, for reasons discussed in Section 8.5.2. These drifts provide space for emplacement of WPs on pedestals using a gantry, or on railbound carts in the center or to one side of the emplacement drift.

As concluded in Section 8.2.1.3, the optimum orientation of subsurface openings at Yucca Mountain from a ground control or stability point of view appears to lie between bearings of N70W and S75W, with approximately east-west being the most favorable direction. The waste emplacement drifts in the interim layout are oriented at a bearing of N72W, near one edge of this most favorable "window" and forming a 75° intersection with the launch/waste handling main. It is considered important that the emplacement drifts be aligned within this window in order to minimize support requirements and to reduce chances that ground support maintenance will be required after emplacement of WPs. In other words, the alignment of openings such as the main drifts and ramps, which can be accessed and maintained throughout all phases of the repository program, is considered to be of considerably lower priority than the alignment of emplacement drifts, where heat and radiation pose formidable problems if maintenance is required.

The N72W orientation selected for this layout was based on a desire to stay inside the favorable window and resulted from graphical inspection that indicated a best fit to the physical shape of the available area and TSw2/TSw3 structure contours on the west side of the Ghost Dance Fault, while maintaining what is judged to be a stable angle of intersection with the main drifts. The selected orientation also helped maximize the length of individual emplacement drifts, which is desirable for operational reasons relating to the use of TBMs as the primary excavation tool. Longer drifts mean lower costs and greater average advance rates because less time is spent in a moving/launching mode, thereby enhancing the utilization of each machine. Additionally, the number of emplacement doors or other fixtures at the entrance to each emplacement drift are minimized.

The basic operational concepts utilized by the interim layout will accommodate other emplacement drift orientations inside the favorable window. Future work should investigate optimization of emplacement drift alignment.

A primary objective in developing the layout was to maintain level gradients in the emplacement drifts to facilitate safety and equipment operational stability aspects of emplacement activities. While this goal has been attained in the layout, future work should investigate introduction of shallow slopes ranging between 0.25 percent and 0.75 percent to provide drainage out of these drifts as stipulated in the CDA (M&O, 1994m, DCSS-009).

Determination of the optimum spacing for emplacement drifts involves a great deal of design analysis to weigh the effects of WP physical characteristics, variability in thermal characteristics and resultant WP spacings against drift diameter and spacing, against various thermal loads and thermal goals, and against long-term drift stability. Closer emplacement drift spacings enhance flexibility in terms of the maximum thermal loading that can be achieved, especially important with the lower thermal energy output packages, but tends to raise costs because a greater unit length of emplacement drift is required per package. However, flexibility is considered crucial because of the limited understanding regarding the thermal loading issue that is available at this point in the ACD effort. For this reason, an emplacement drift spacing of 22.5 meters is used in the interim layout shown on Figure 8.6.3-1, and is considered to be a minimum in terms of the long term stability of the pillars and intersections formed where the emplacement drifts and crosscuts intersect the two main drifts along the east side of the layout. A great deal of work remains to be performed in this area.

8.6.4.7 South Ramp

The South Ramp will be excavated during site characterization. It will be 7.62 meters in diameter. The ramp includes a 305 meter radius curve which connects to the service main and completes the primary loop to be excavated during ESF construction.

In the interim layout the South Ramp serves as the primary access for transportation of personnel, equipment and materials to the subsurface for support of repository development operations. It would also serve as the main ventilation intake airway for the development side of the repository. This configuration was identified as a potential alternative concept in M&O, 1993a, (p. 5-51) and differs from concepts presented in M&O, 1993b and M&O, 1994a.

Title I ESF design (YMP, 1993g) located the south portal next to the nose of a ridge on the southeast flank of Yucca Mountain. As presented in M&O, 1993b and M&O, 1994a, and for purposes of the interim layout, the same ridge was utilized but the portal was moved downhill and farther to the east in order to maintain a slope on the ramp of less than 3.0 percent, consistent with the CDA (M&O, 1994m, DCSS-009), but still above the probable maximum flood plain. The resulting slope of the ramp is minus 2.37 percent.

The ramp was oriented by inspection to lie directly beneath the spine of the portal ridge, a practice generally considered to be favorable in terms of opening stability. When extended straight into the mountain, this orientation gave a reasonably good fit with the emplacement block area and kept gradients comfortably beneath the 3.0 percent maximum.

The South Ramp could be configured during repository development as shown in the general cross section of Figure 8.6.4-4. Utilities installed in the ramp and shown in that figure are discussed in Section 8.10.3. The ramp is configured with two electrical trolley rail lines, one for downgrade and one for upgrade haulage. Two tracks will minimize the potential for a bottleneck to develop in the ramp during materials transport, the function that will require the greatest use of the track. Safety will also be enhanced because the same track will not be used for travel in opposing directions under normal operations. Two tracks will also add flexibility to transport personnel and materials if one track is damaged or in need of maintenance, prior to repairs, without completely shutting down the supply corridor to the development area.

A second feature that could be incorporated into the design of a two-rail line system is the use of the outer rails of the two tracks or the inner rails of the two tracks as "wide-load" rail lines. This concept would be useful when moving large items into or out of the repository. Examples include service platforms, major TBM components and launching equipment, and other uses where a wider wheel base carrier may be advantageous.

8.6.4.8 South Ramp Extension

The South Ramp extension continues in a westerly direction for approximately 180 meters from its point of intersection with the South Ramp. It then curves northwest and enters another tangent section, approximately 900 meters in length, that terminates in a final curve that turns the ramp extension North. At this point, it connects to a short section of service main that parallels, and then intersects, the ventilation perimeter main. The ramp extension is 7.62 meters in diameter, consistent with other main drifts in the layout that function as primary accesses and ventilation airways, but are not used for waste emplacement operations or for TBM launching and retrieval. Figure 8.6.4-5 is a section taken along the South Ramp and South Ramp extension showing the relationship between these drifts and geological and other surfaces plotted using the Lynx computer model. The layout of this drift as shown on Figure 8.6.4-5 differs significantly from that shown on Figure 8.1-7. The change is a result

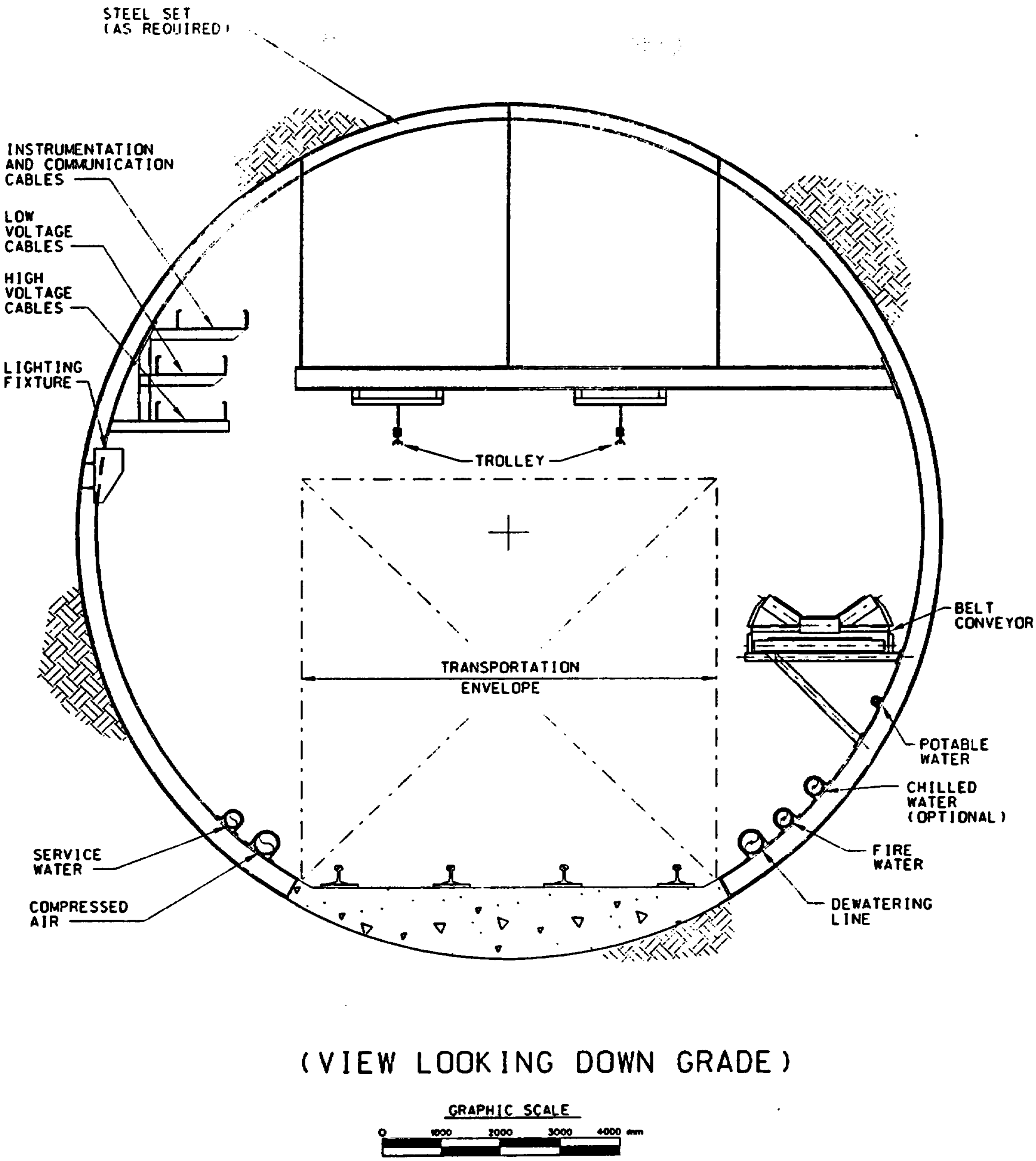
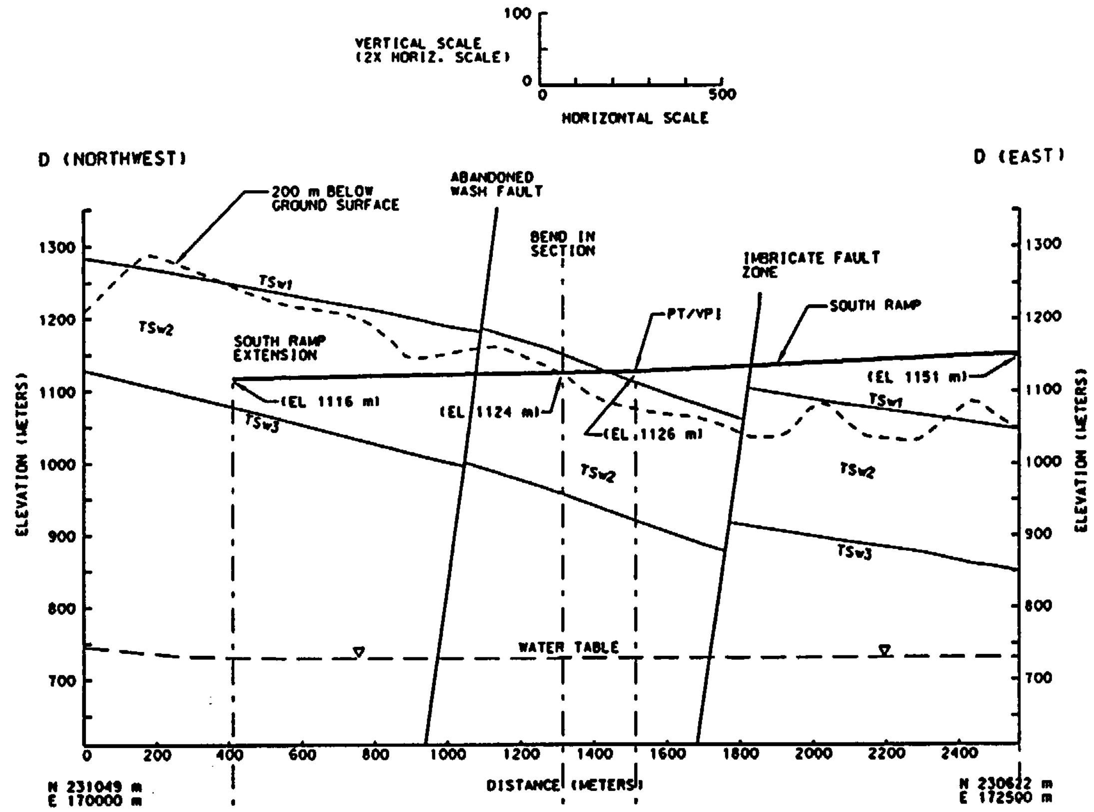
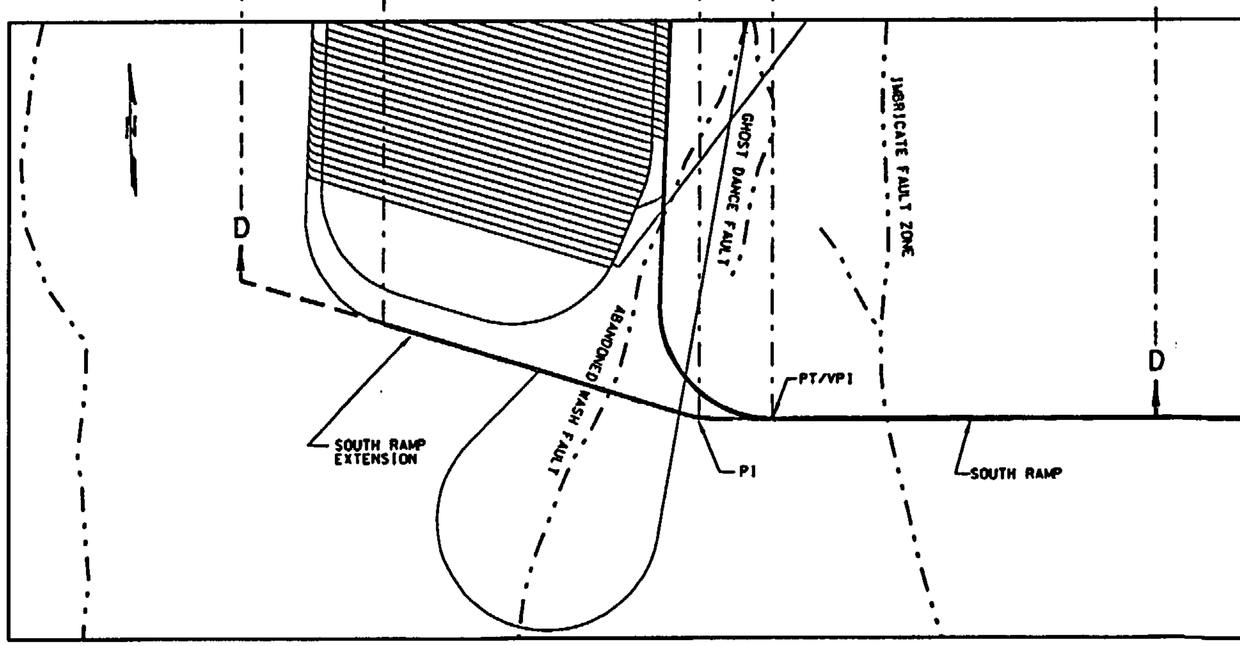


Figure 8.6.4-4. South Ramp Cross Section (During Development Operations)



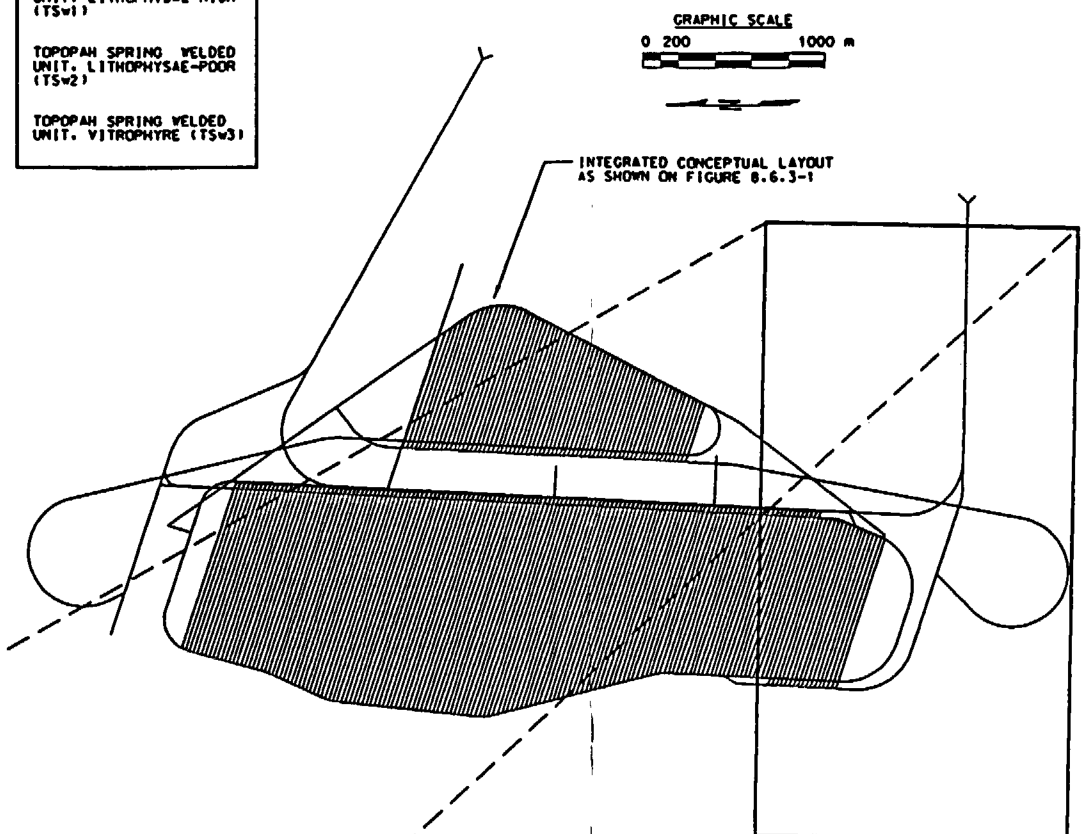
SECTION D



ENLARGED PARTIAL PLAN

GRAPHIC SCALE
0 100 500 m 1000 m
1:10000

REFERENCE THERMAL/ MECHANICAL STRATIGRAPHY UNIT NAME (DESIGNATOR)
TOPOPAH SPRING WELDED UNIT, LITHOPHYSAE-RICH (TSw1)
TOPOPAH SPRING WELDED UNIT, LITHOPHYSAE-POOR (TSw2)
TOPOPAH SPRING WELDED UNIT, VITROPHYRE (TSw3)



NOTES:

1. TSw SURFACES SHOWN IN SECTION WERE DEVELOPED FROM USGS LYNX MODEL YMP.R1.0 (MAY 11, 1994). MODIFIED BY M&O TO REFLECT SAIC/SMF STRATIGRAPHIC PICKS FOR TSw2 SURFACES (M&O DESIGN ANALYSIS BC0000000-01717-0200-00003, REV.000)
2. FAULTS SHOWN IN SECTION ARE FROM USGS LYNX MODEL YMP.R1.0 (MAY 11, 1994)
3. WATER TABLE IS FROM M&O DESIGN ANALYSIS BC0000000-01717-0200-00003, REV.000
4. ELEVATIONS DEPICTED ARE AT EXCAVATED INVERT OF OPENING.

CONCEPTUAL

FIGURE 8.6.4-5

SECTION SHOWING STRATIGRAPHY ALONG SOUTH RAMP AND EXTENSION

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With the exception of the final curve, the extension would be excavated during site characterization to provide a second east-west crossing of the potential repository block to explore for major, north-south trending geologic features. It may be used as a launch point for exploratory drifting access to the underlying Calico Hills unit. Because it traverses most of the TSw2 unit, approaching within approximately 40 meters of the underlying vitrophyre, this drift might also be utilized for numerous site characterization tests in the TSw2 unit.

During repository operations, this drift would provide access to the short section of service main located on the west side of the potential repository block. It would function as a primary ventilation airway for development operations during the period when the adjacent section of service main is supporting emplacement drift excavation.

If lower thermal loadings or other conditions result in the need to develop an emplacement area east of the Ghost Dance Fault, then this extension provides a launch point for driving a development operations access ramp to a lower block. (An emplacement block located east of the primary block would have to be significantly lower due to the eastward dip of the formation.)

8.6.4.9 Development Side Ventilation Shaft

A ventilation shaft is included in the interim layout and is the primary development side exhaust airway. The primary reason for this is if electric trolley (rather than diesel) powered locomotives are used, then personnel and materials transport can be better accomplished in an intake airway, i.e., in the South Ramp.

The shaft is conceptually located on the southeast flank of Yucca Mountain, adjacent to an access road leading to the crest. This position gives the shaft a depth of approximately 210 m from the collar to the invert of the upper emplacement block shaft station, excluding an additional allowance for a sump. More comprehensive shaft siting studies will be performed to investigate this site as well as several other potentially suitable sites located on the southern end of the upper, or primary emplacement block.

The required inside diameter of this shaft is preliminarily estimated to be 4.1 m. This estimate is based upon the minimum shaft size necessary, allowing for a small amount of area reduction for shaft utilities, to carry a design air volume of 217.6 m^3/s (Section 8.8.1), plus a 20 percent contingency allowance, at a maximum velocity limit of 20.3 m/s (M&O, 1994m, DCSS-0016). A 20 percent contingency provides the flexibility to provide a third TBM operation for emplacement drift excavation if necessary, plus provide a small reserve without exceeding shaft velocity limits. A third TBM operation could become necessary if scheduling delays were encountered during construction or if accelerated development was needed.

Without the contingency airflow, a normal air velocity of approximately 17 m/s would be present in the shaft at a 4.1 m diameter. This velocity equates favorably with a range of general economic airflow velocities of 18 to 20 m/s for concrete lined shafts free from steelwork (Burrows, 1982, p. 272). An excavated diameter of approximately 4.5 m would provide a nominal 200 mm thick allowance for a permanent concrete lining or other ground support method.

Since there are two shafts planned (see Section 8.6.4.10) in the interim repository layout, and since a mechanical shaft excavator is a preferred and feasible approach to construct the shafts (M&O, 1993a, pp. 5-1 & 6-4), standardization of shaft diameters should be investigated, from a cost savings standpoint. This would mean that the development shaft size would be increased to match the emplacement side ventilation shaft lined diameter of 6.1 m and excavated diameter of 6.7 m (Section 8.6.4.10).

To potentially achieve such a cost savings, however, would require that the two shafts be scheduled to be excavated sequentially during initial repository construction and under a single contract. This concept has merit because shaft construction using mechanical excavators is a specialty construction item. A relatively small number of contractors have the proven experience and equipment necessary to perform this type of work. Machine mobilization and demobilization cost savings would result, shaft lining cost savings could potentially result through the use of the same set of concrete forms (or optionally precast segment sizes), work deck, and plant for both shafts. Labor costs would not be significantly different between the two sizes, however, material costs for lining and excavation would increase for the development shaft.

Since the shaft excavated volume would increase by more than 200 percent if the size were increased, a more rigorous cost analysis would be necessary to determine if a true savings would exist. In addition, the waste isolation ramifications of such an increase would need to be investigated. In the absence of these investigations, the preliminary finished size for the development side exhaust shaft is set at 4.1 m diameter. A general cross section of the shaft is shown in Figure 8.6.4-6. Utilities installed in the shaft and shown in that figure are discussed in Section 8.10.3.

The 4.1 m diameter development shaft described above is smaller than that used for the development side personnel and materials/development intake shaft in the SCP-CD repository design (SNL, 1987a), which had a lined diameter of 6 m. A primary reason for the difference was that the SCP-CD shaft size was controlled by operational requirements for hoisting rather than ventilation.

8.6.4.10 Emplacement Side Ventilation Shaft

An emplacement side ventilation shaft will function as the only ventilation exhaust airway on the emplacement side of the repository. It is conceptually located in the interim layout on the nose of a ridge located between Drill Hole and Teacup Washes and has a depth of approximately 310 m to the upper emplacement block. More comprehensive shaft siting studies are required to investigate the geologic suitability as well as the radiological safety and waste isolation aspects of the site.

If the shaft were sized only to support emplacement side operations as described in Section 8.8.2 plus a reasonable contingency, a relatively small lined diameter of approximately 3.7 m would result based upon general economic airflow velocities of 18 to 20 m/s in concrete lined shafts free from steelwork (Burrows, 1982, p. 272). But this size is considered too small to reasonably accommodate potentially higher quantities that might be needed for emplacement drift cooling.

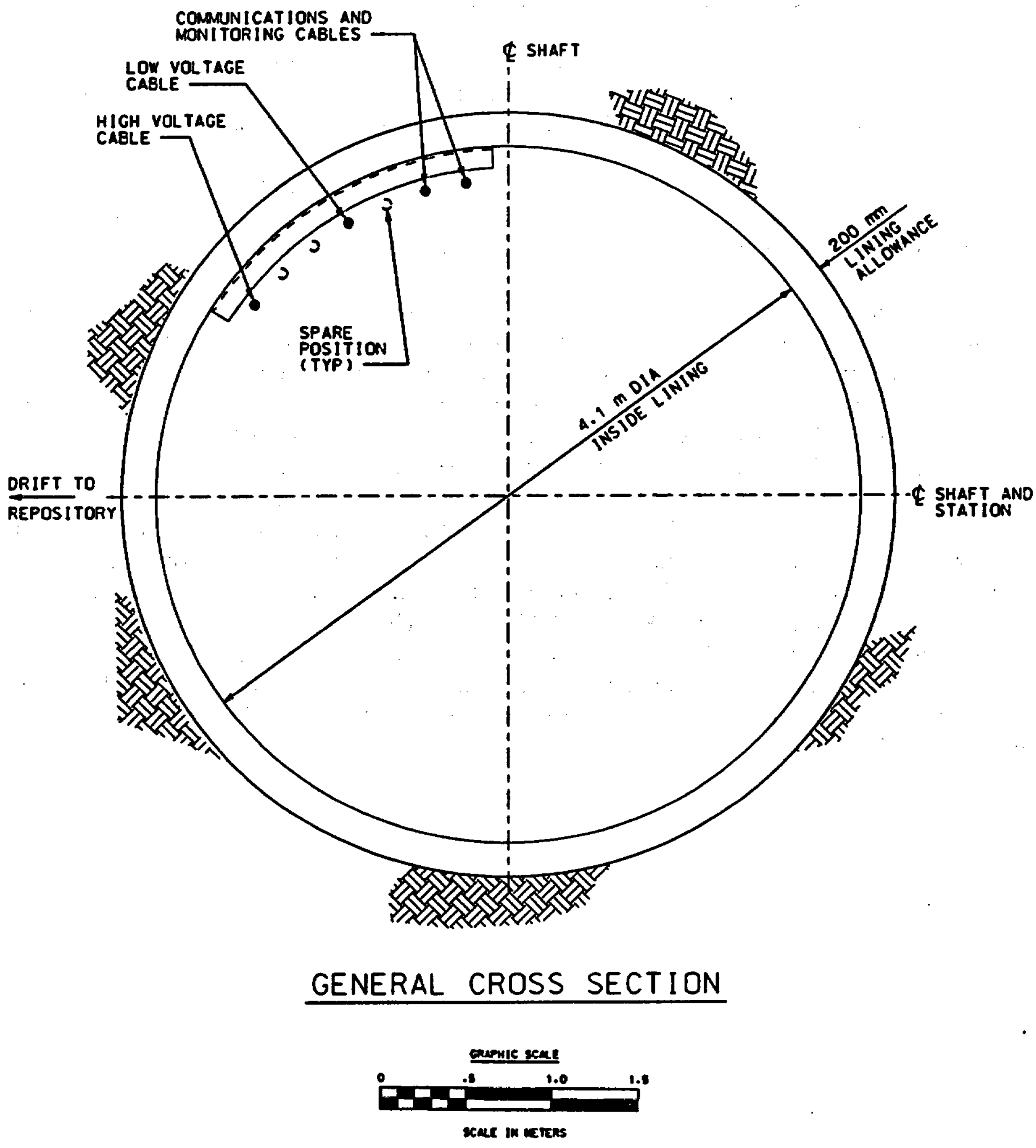


Figure 8.6.4-6. Development-Side Exhaust Shaft-Cross Section

To allow for emplacement drift cooling, which may be needed for retrieval or other activities such as WP performance confirmation or thermal management, the shaft is conceptually sized by using the lower value from two approaches. The approaches are summarized in Table 8.6.4-1, and use as their basis the current ventilation air velocity limitations included in the CDA (M&O, 1994m, DCSS-016). The two approaches consider the following:

A. The maximum intake air quantity that can be obtained, based upon opening sizes and air velocity limits, for all surface-based openings into the repository that could be used as intake air paths once all development operations are completed.

B. The maximum exhaust air quantity that can be expelled, based upon opening size and air velocity limits, from all available subsurface exhaust airways (i.e., the perimeter main and other minor drifting in the interim layout configuration).

The value obtained from the second approach is the limiting quantity that could be exhausted from the shaft based upon current project ventilation velocity limitations using the ventilation network for the interim layout without adding additional subsurface exhaust airways or revising current project velocity limitations. A quantity of 584 m^3/s (minus the 33 m^3/s shop flow that goes directly to exhaust) would be sufficient to cool approximately three drifts at a time at a relatively high flow per drift of 150 m^3/s (see Section 8.12.5).

If the quantity of 584 m^3/s is used, and a velocity limit in the shaft is set at 20 m/s, the lined diameter of the shaft is 6.1 m. The 20 m/s velocity is at the high range of economic velocities for shafts free from steelwork (Burrows, 1982, p. 272) and is virtually at the current velocity limit of 20.3 m/s (M&O, 1994m, DCSS-016). This size is comparable to that used for the emplacement exhaust shaft in the SCP-CDR repository design which had a lined diameter of 6 m (SNL, 1987a). An excavated diameter of approximately 6.7 m would result using a nominal 300 mm thickness allowance for a permanent concrete lining or other ground support method.

Table 8.6.4-1. Preliminary Emplacement Side Ventilation Shaft Size Basis

Airway	Excavated Diameter (m)	Gross Area (m^2)	Approximate Net Area[1] (m^2)	Maximum Velocity[2] (m/s)	Maximum Airflow Quantity (m^3/s)
North Ramp	7.6	45	38	7.6	289
South Ramp	7.6	45	36	7.6	274
Development Side Shaft	4.5	16	13	20.3	264
Total Quantity - Approach No. 1					827
Perimeter Main Drift	9.0	64	54	10.2	551
Support Shop	n/a	n/a	n/a	n/a	33
Total Quantity - Approach No. 2					584

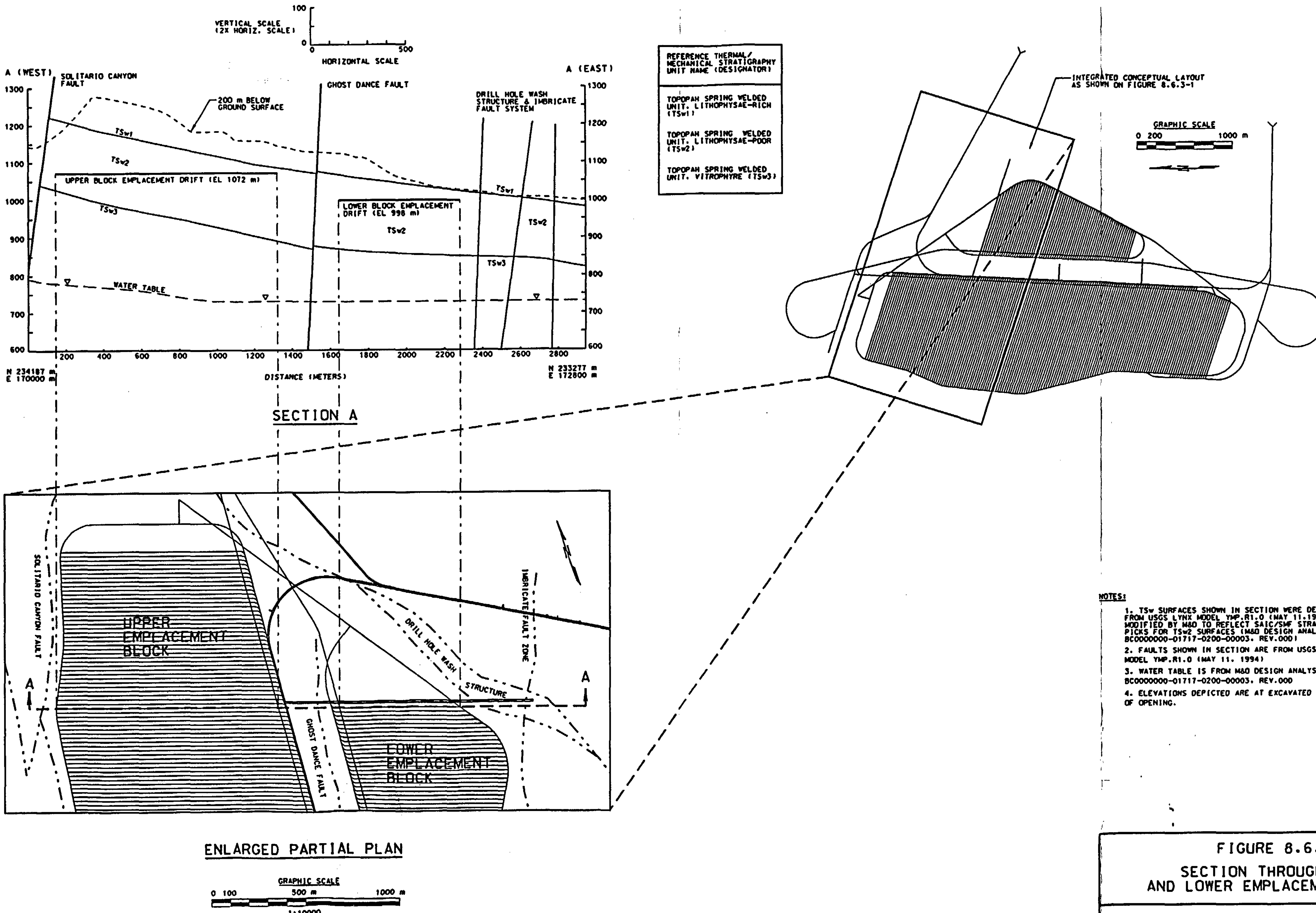
1) Approximate allowance for ground support, permanently installed utilities and equipment, and invert (as applicable).
2) Based upon current project maximum values as stated in the CDA (M&O, 1994m, DCSS-016).

8.6.4.11 Lower Emplacement Block

The emplacement area situated between the Ghost Dance Fault and Imbricate Fault systems is called the "lower block" because it is situated at an elevation that is approximately 70 meters lower than the primary, or "upper" emplacement block situated to the west as shown in Figure 8.6.4-7.

The lower block was designed using the same objectives that were used for the upper block. The design objective that specifies flat-lying emplacement drifts was the main "driver" that led to the "step" down from the primary block, due to the eastward dip of the TSw2 unit. The selected horizon was established by: 1) picking a location for the farthest north emplacement drift that would leave adequate space for the ESF Main Test Area (MTA); 2) overlaying surface topography on the structural contours for the TSw1/TSw2 contact; 3) and establishing an elevation for this drift that was near the top of the TSw2 unit while complying with the 200 meters cover requirement and then iterating through several main drift layouts that satisfied all of the objectives and requirements listed in Section 8.6.1.

The upper block would be fully emplaced before emplacement operations move to the lower block. Operationally, the development and emplacement schemes in the lower block would



NOTES:

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4. ELEVATIONS DEPICTED ARE AT EXCAVATED INVERT OF OPENING.

CONCEPTUAL

FIGURE 8.6.4-7

SECTION THROUGH UPPER AND LOWER EMPLACEMENT BLOCKS

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be the same as for the primary block. Both operations would proceed from North to South, and the functions of the various drifts would be the same.

Access to the lower block would be provided using minus 3.00 percent ramps that originate from the lower reaches of those connecting the primary block to the surface. Additionally, the two ventilation shafts would connect to the lower block emplacement area main drifts.

It is envisioned that construction of the ramps and the main drifts for the lower block would be carried out as a more or less independent operation on the development side of the repository during development and emplacement of the upper block. The North Access Ramp to the lower block would be developed from the bottom up in order to maintain separation of ventilation systems. Both shafts would be sunk to full depth at the time of original construction.

Depending upon the amount of emplacement area that may be required, it should be pointed out that development of a separate emplacement block in the area shown may not be the best choice. Access ramps and main drift requirements, in relation to the reduced length and number of emplacement drifts that are provided, could be excessive when compared to other potential expansion areas (Figure 8.3.2-3). Thermal and thermal-hydrological concerns may also exist due to possible interactions between the upper and lower blocks.

8.7 DESCRIPTION OF SUBSURFACE OPERATIONS

Operational concepts associated with the interim layout are described in this section, first for the development and then for the emplacement side of the repository. Development concepts discussed include the excavation, excavated tuff handling, and transportation methods for personnel and supplies. Emplacement operations descriptions begin with an overall presentation of radiological boundaries for the emplacement side. A philosophy for crossing radiological boundaries that interface with both the development and emplacement sides is presented, and this philosophy forms the basis for several preliminary concepts presented in other sections of the report. Other preliminary concepts are presented for in-drift emplacement operations using two different methods of WP support and associated emplacement equipment. A brief discussion of key aspects associated with emplacement drift monitoring, and personnel and supplies transport in the emplacement side is also made.

8.7.1 Development Operations and Equipment

Development side operations in the repository will commence several years before approval of the license application with the NRC to emplace waste is granted. In the SCP-CD, this period was estimated at six years. The following subsections present a basic summary of several key operations in the development side using the interim layout shown in Figure 8.6.3-1 as the basis. A more up-to-date estimate of preemplacement construction has not been developed yet during ACD. After approval to emplace waste is granted, development and emplacement side operations will be conducted concurrently until all portions of the repository have been constructed. This period would be completed prior to completion of emplacement operations and would be scheduled to minimize premature capital expenditures.

8.7.1.1 Excavation System Description

Figure 8.7.1-1 presents the arrangement of subsurface openings comprising the upper block of the interim layout. As mentioned in Section 8.6, excavation of the TBM launch main, the perimeter ventilation main, and the ventilation shafts would occur during the initial stage of repository construction, prior to emplacement of waste. Excavation of the short section of service main located just north of the bottom of the North Ramp, and the short section in the southwest corner that joins with the South Ramp extension, would also occur at this time.

Upon completion of this system of main drifts, or "mains," excavation of emplacement drifts would begin. Emplacement drift construction would begin at the north end of the layout and would proceed sequentially toward the south. It is envisioned that the construction of approximately 10 to 25 emplacement drifts would have to be completed prior to emplacement of waste in order to facilitate access to the waste handling main, to establish proper ventilation circuitry and to allow erection of substantial stoppings or bulkheads in the mains to provide physical separation of development and emplacement operations.

Figure 8.7.1-2 is an enlarged view showing the typical arrangement of openings in the service main/launch main portion of the layout. Prominent features on this figure include the crosscuts that interconnect the service and launch mains. Excavation of each of these crosscuts would precede excavation of its adjoining emplacement drift, as the crosscut

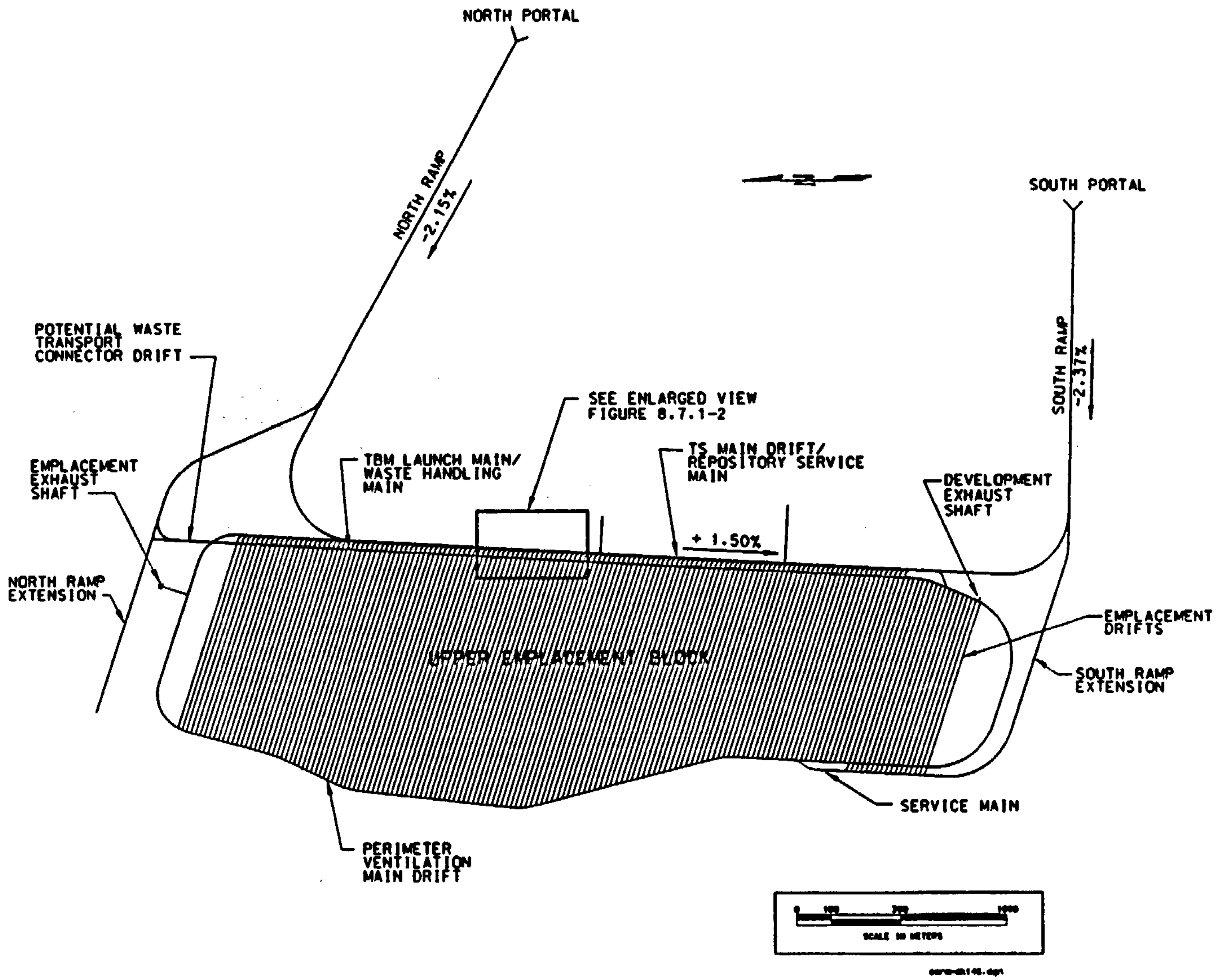


Figure 8.7.1-1. Conceptual Repository Layout Upper Emplacement Block

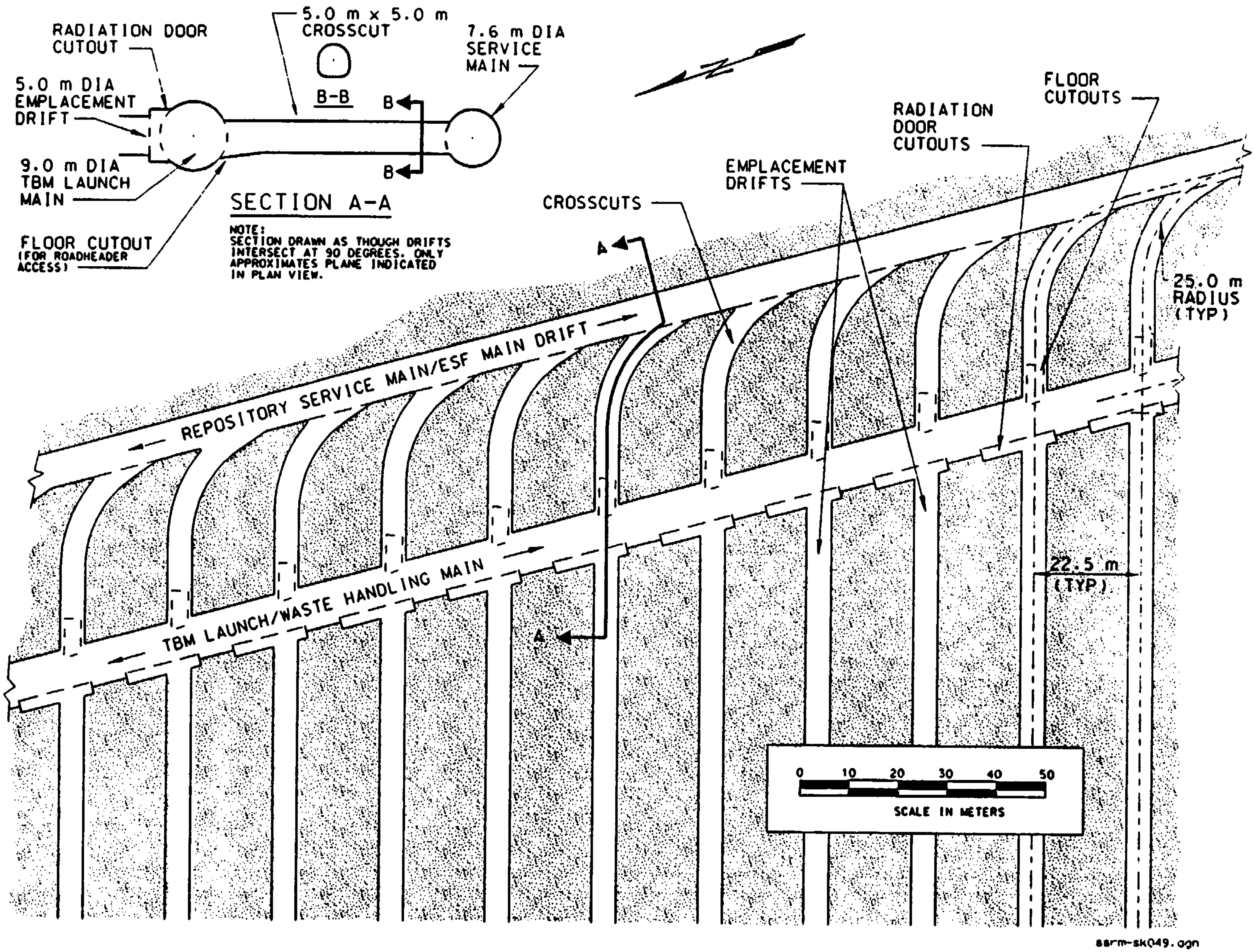


Figure 8.7.1-2. Detailed Layout of Drifting in Service/Launch Mains Areas

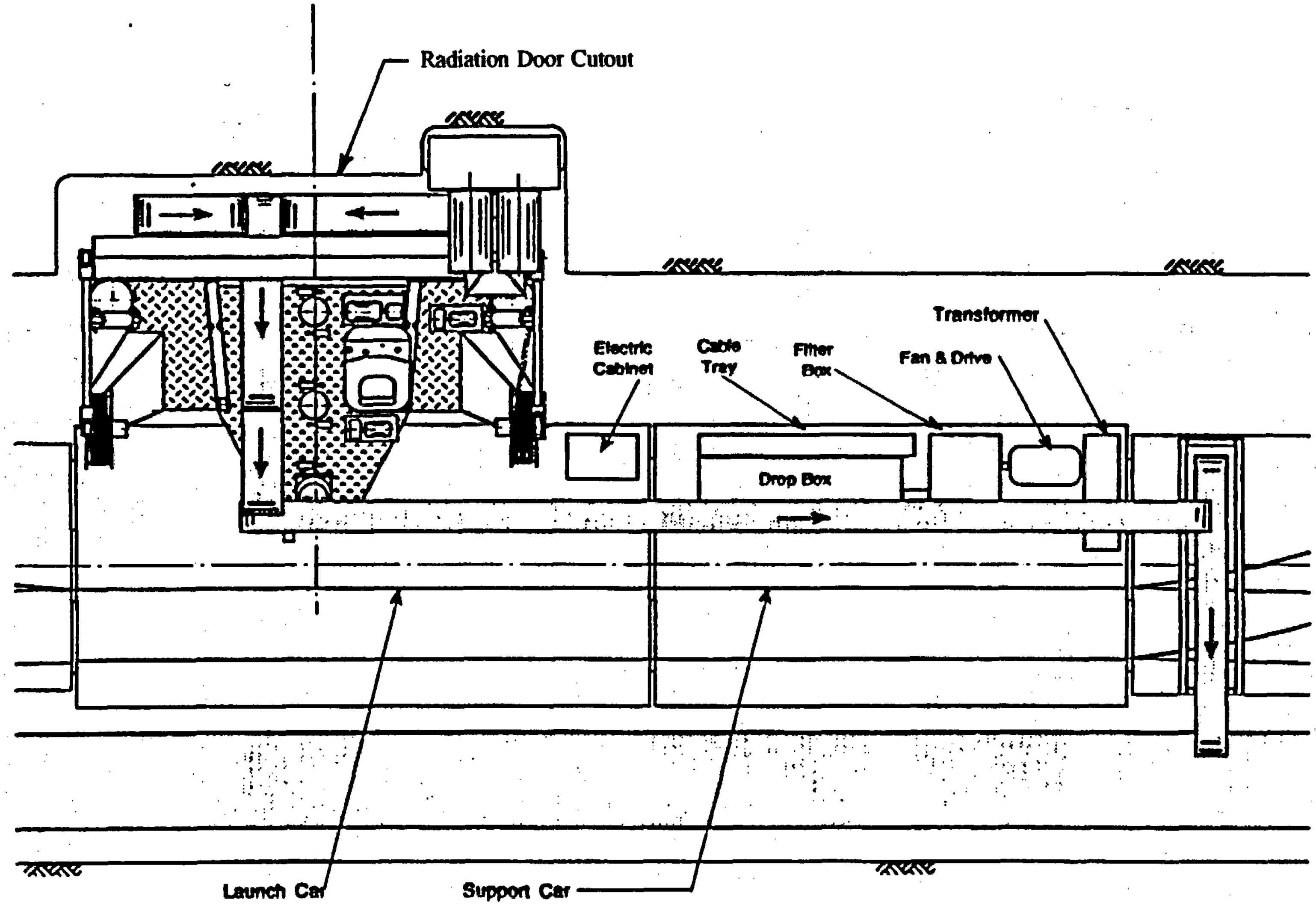


Figure 8.7.1-3. Plain View of CSM Alcove Miner at Radiation Door Cutouts

provides the development operations access link between the emplacement drift and the service main. The crosscut is curved (25 meter radius) to permit installation of a railway system to support TBM excavation of the emplacement drift and to service follow-on construction in the emplacement drift necessary to prepare it for receiving WPs.

It is envisioned that excavation of the crosscuts would be performed using a specially designed alcove miner to create a starting cut for a heavy-duty roadheader that would then be used to complete the rest of the crosscut. Section 8.4.2.1 discussed the limitations of currently available roadheader machines in the TSw2 unit, but also pointed out that the Colorado School of Mines (CSM) has designed both an alcove miner and a special cutting head for a roadheader that uses mini-disc cutters rather than conventional "pick" style bits. It is assumed that this, or similar technological advances, will be fully developed, tested, and available for repository secondary excavation tasks. A specialized, forward gripper, unshielded TBM may also be adapted for this requirement, but for purposes of this discussion it is assumed that the alcove miner and a modified, heavy-duty roadheader will be developed.

Both the alcove miner and the roadheader would operate out of the launch main and would advance the crosscut toward the service main. This approach would minimize disturbance to operations associated with actual emplacement drift excavation/construction and would help prevent contaminated ventilation air exhausted from these operations from polluting the air stream used by the other operations. Crosscut excavation would be maintained several positions ahead of emplacement drift excavation. Roadheader muck would be discharged onto a segmental conveyor or into a shuttle car and would then be transferred into a railbound muck car situated in the closest crosscut accessible from a switching platform located in the service main. The muck car would then travel to and discharge in the primary conveyor feeder located in the service main.

Another feature shown on Figure 8.7.1-2 is an enlargement, or cut-out, in the launch/waste handling main at the mouth of each emplacement drift. These are for installation of concrete filled radiation doors, approximately one meter thick, that cover the entrance to each emplacement drift and provide shielding for emplacement operations personnel on the emplacement side of the repository. Excavation of each cut-out and the starter cut for the adjoining crosscut would be performed sequentially from north to south during development operations by the alcove miner shown on Figure 8.7.1-3. Cut-outs for radiation doors are also required at the opposite ends of the emplacement drifts. These would be excavated one at a time by an alcove miner immediately following removal of the TBM as it completes each emplacement drift. This will permit utilization of the ventilation duct system already hung in the drift, for exhausting dusty air generated during cut-out excavation.

A single alcove miner/roadheader operation should provide sufficient coverage of crosscut and radiation door cut-out excavation to support two TBMs performing emplacement drift excavation. When a TBM is brought into the launch main to begin excavation of another emplacement drift, the alcove miner, roadheader, and various support equipment would be temporarily moved into a crosscut to permit the TBM carrier to pass.

Construction of an emplacement drift involves several successive stages as follows:

A. Launch TBM.

B. Excavate emplacement drift with TBM, installing precast concrete invert segments, rail, utilities, and permanent ground support as the machine advances.

C. Following completion of drift excavation, install any additional permanent ground support deemed necessary and construct a cast-in-place concrete invert to support a permanent rail system used to facilitate waste emplacement, while removing utilities and other materials originally installed to sustain excavation process. (Utilities and other materials that are removed would be reused in other emplacement drifts that are being excavated at the same time.) This work would be performed on a retreat basis, i.e., from the far end of the emplacement drift, back toward the service main.

D. Install permanent rail and supports or trackway for remote video monitoring, instrumentation equipment, or similar devices in the emplacement drift.

E. Construct radiation doors at the ends of the emplacement drift.

In order to permit all of the work outlined above to be performed concurrently, it is necessary to provide construction access to at least five emplacement drifts at any given time. In reality, probably twice that number would be needed, (i.e., access to ten emplacement drifts might be desirable) in order to permit adequate flexibility during development operations.

To accommodate access to multiple emplacement drifts in varying stages of construction, a switching or service platform as depicted on Figures 8.7.1-4, 8.7.1-5, 8.7.1-6, and 8.7.1-7 would be utilized. This platform would be designed and fabricated to include the following attributes:

A. The platform would be fabricated in sections, six to fourteen meters long, to facilitate transportation into the subsurface and to permit repositioning of the platform one or two sections at a time, if necessary. Adjacent sections would be joined using simple pin connections.

B. Each section would be outfitted with steel wheels to facilitate moving the platform in individual or multiple sections along rail attached to precast concrete segments in the service main invert.

C. Sections would be equipped with lifting and anchoring systems that allow the platform to elevate and be supported by its wheels for relocating or repositioning, then set down on adjustable, fixed supports to relieve wheel loads and accommodate temporary anchoring of the platform to the invert and walls of the tunnel to provide stable working conditions.

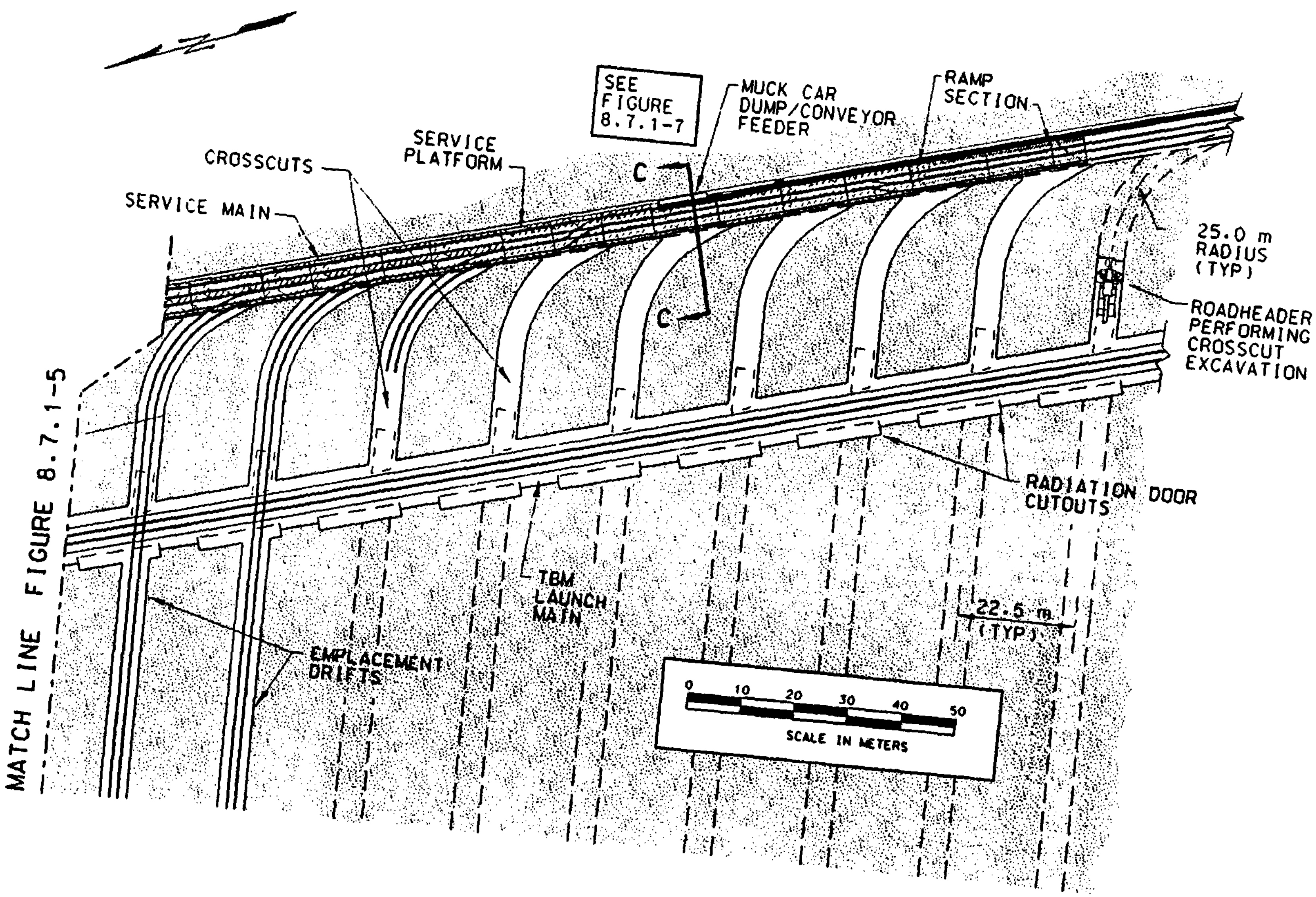


Figure 8.7.1-4. Service Platform-North End

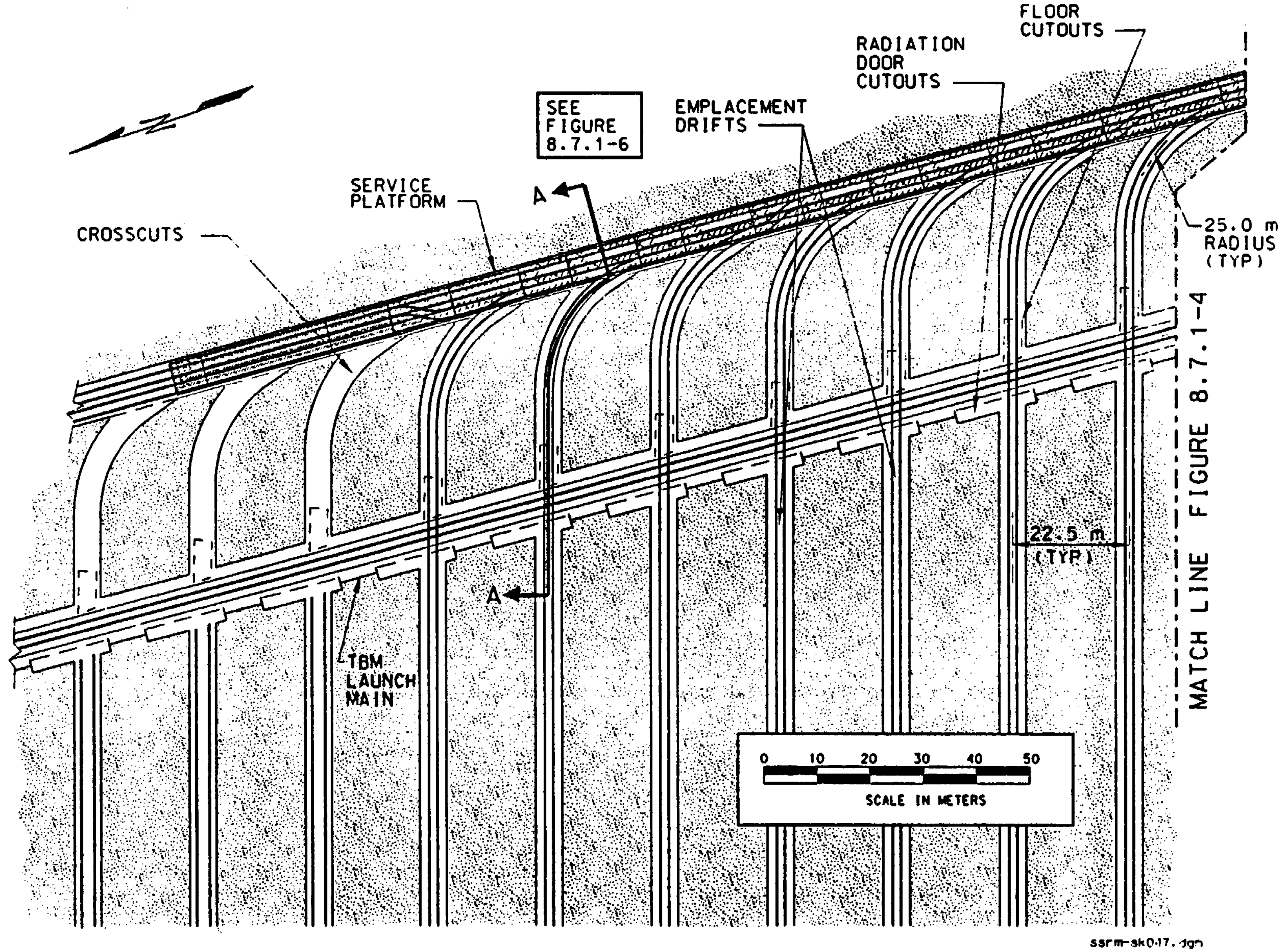


Figure 8.7.1-5. Service Platform-South End

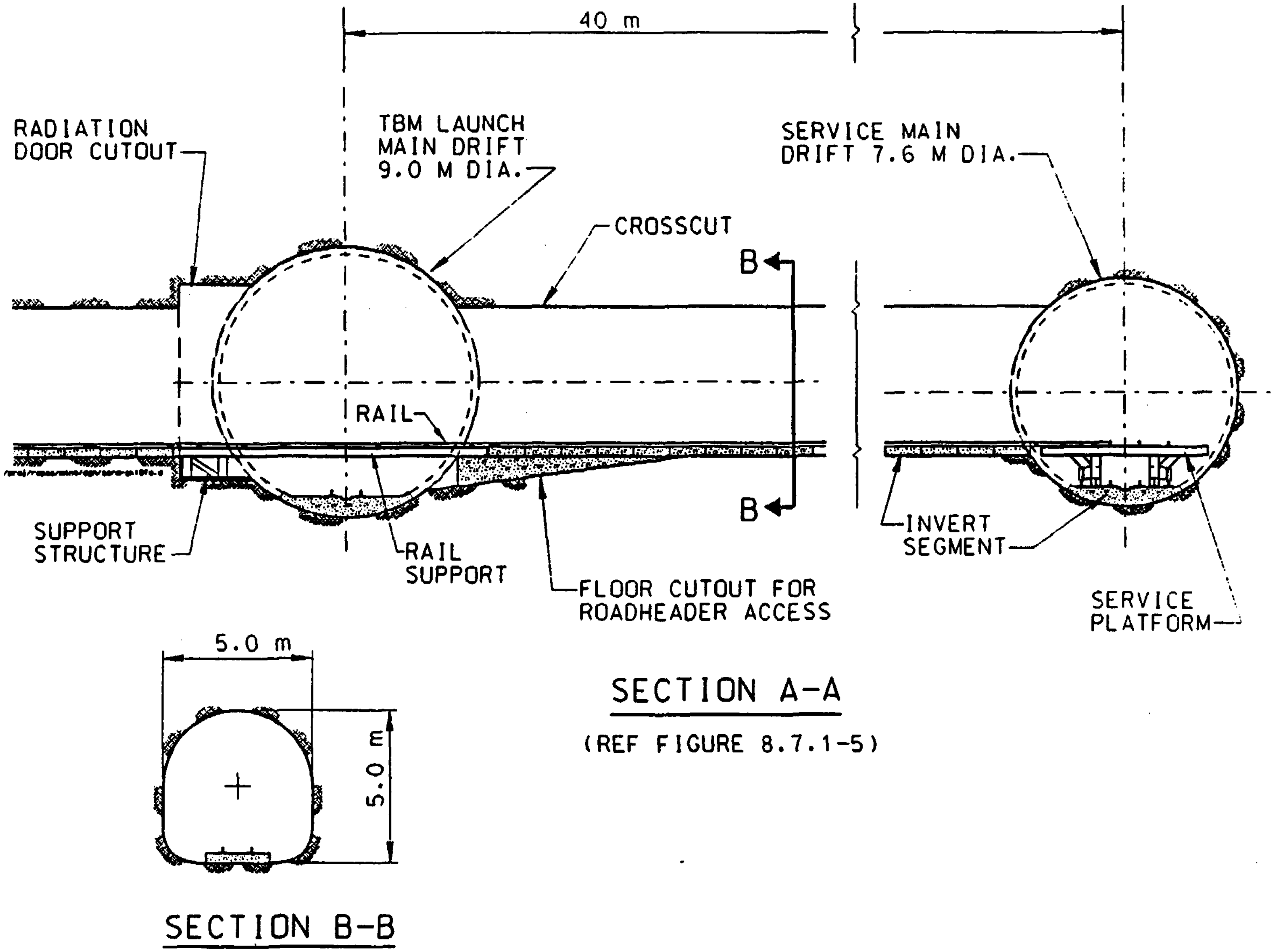


Figure 8.7.1-6. Service Platform-Section Through Crosscut

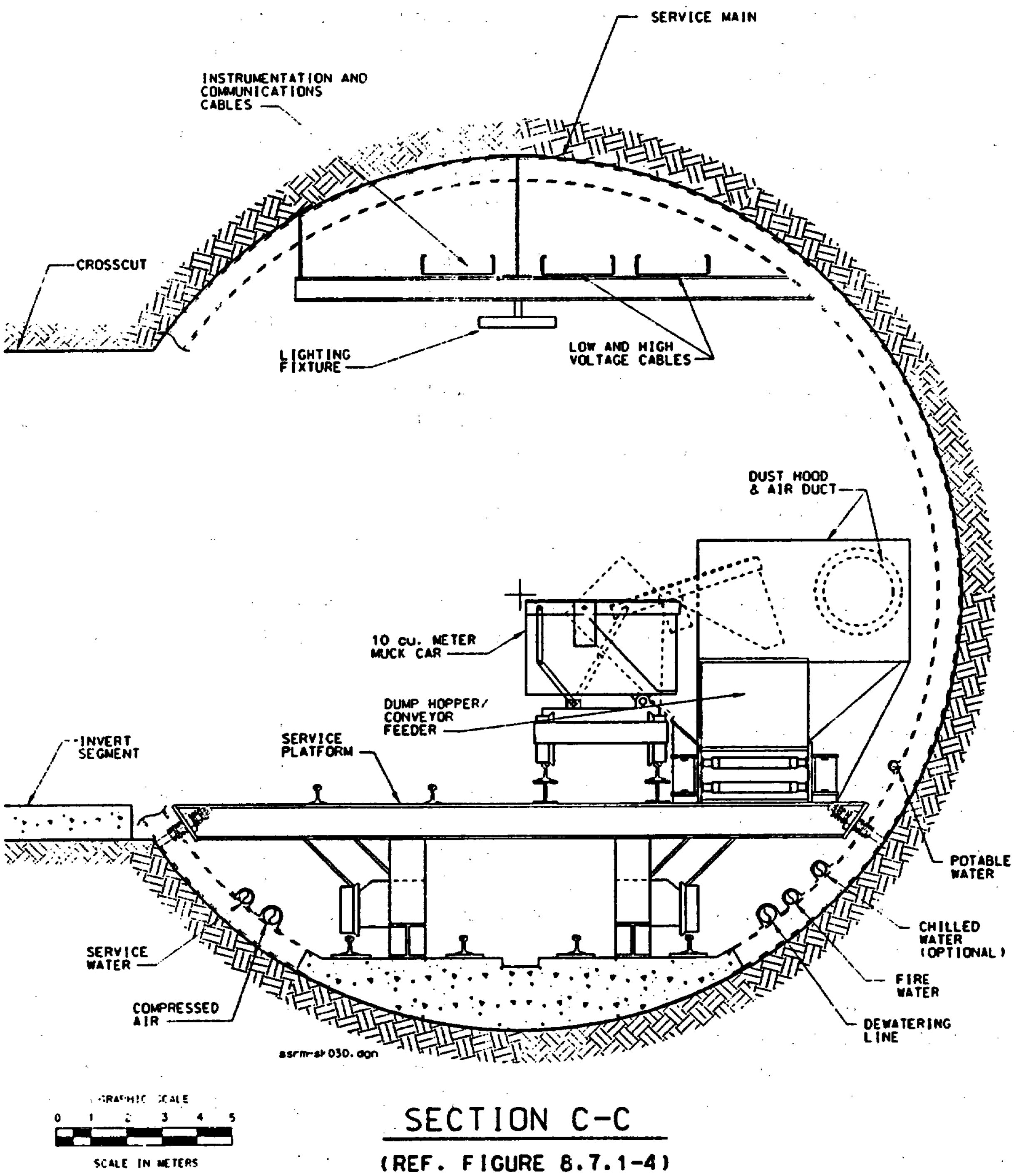


Figure 8.7.1-7. Service Platform-Muck Car Dump Point

D. The top of the platform would be decked with expanded metal or a similar, nonskid surface and would have two sets of rail trackway installed. Rail switches would be installed on one track and spaced to coincide with the centerline spacing of the crosscuts and emplacement drifts. Crossover switches would be installed to permit access from one trackway to the other.

E. Racks or similar devices would be mounted along various sections of the platform to accommodate temporary storage of pipe, rail, fanline and other utilities or materials used in construction of the emplacement drifts.

F. A train dump and conveyor feeder station would be located at the south end of the platform to facilitate offloading of excavated muck from the emplacement drifts and crosscut excavation onto a conveyor system for transport out of the tunnel.

G. Each end of the platform would terminate in a ramp section that allows trains to transition from the permanent rail system attached to the tunnel invert, to the elevated railway attached to the top of the platform.

Figures 8.7.1-4 and 8.7.1-5 show the platform situated to provide rail access to ten crosscuts and their adjoining emplacement drifts at one time. Four or five of these drifts would be in various phases of construction following excavation. The remainder would either be in the process of being excavated or next in line for excavation. The southernmost crosscut accessed by the platform would be used by the crosscut/cut-out excavation operation for muck and materials haulage.

Postexcavation construction in the emplacement drifts would be scheduled so that it keeps pace with the rate of TBM excavation of the drifts. When excavation of the last emplacement drift accessible from the platform is completed, the platform would be moved to the south and repositioned so that drifts requiring postexcavation construction are accessed from the north end of the platform, while the south end is situated to permit access to four or five more drifts to be excavated. The platform would be moved periodically toward the south in this manner throughout most of the repository operational period, until construction of the emplacement drifts is completed.

As mentioned above, actual emplacement drift construction begins with "launching" the TBM. Traditionally, this task has been accomplished by excavating a short starter tunnel or "launch chamber" beforehand, using non-TBM methods, then constructing gripper pads made of concrete or timber to provide reaction points for the grippers, so they in turn can provide a reaction for the thrust necessary to propel the machine forward. For most tunnels this is a one-time operation; a more mechanized approach is not warranted.

The interim layout, however, requires numerous launchings of the emplacement drift TBMs. In order to simplify these launchings without having to perform costly and time consuming starter tunnel excavation, emplacement drift TBMs for the interim layout would be designed with a relatively small length to diameter (aspect) ratio, on the order of 1.25 : 1.0 or lower, not including the machine conveyor and tail shield sections which can be designed to permit easy removal and reinstallation. (The aspect ratio for the 7.62 meter diameter TBM being built for the ESF program is approximately 1.28 : 1.0, with tail shield and machine conveyor removed.) This criteria would permit the 5.0 meter diameter emplacement drift TBMs to be rotated in the 9.0 meter diameter launch main without the need for additional excavations. Given a relatively short TBM, all that is needed to facilitate launching from the larger diameter opening is a mechanical framework that will stabilize the machine and provide a reaction for thrust as it begins boring. A mechanized approach for accomplishing this task in a relatively short period of time is depicted on Figures 8.7.1-8, 8.7.1-9, and 8.7.1-10.

A typical launch would be performed as follows:

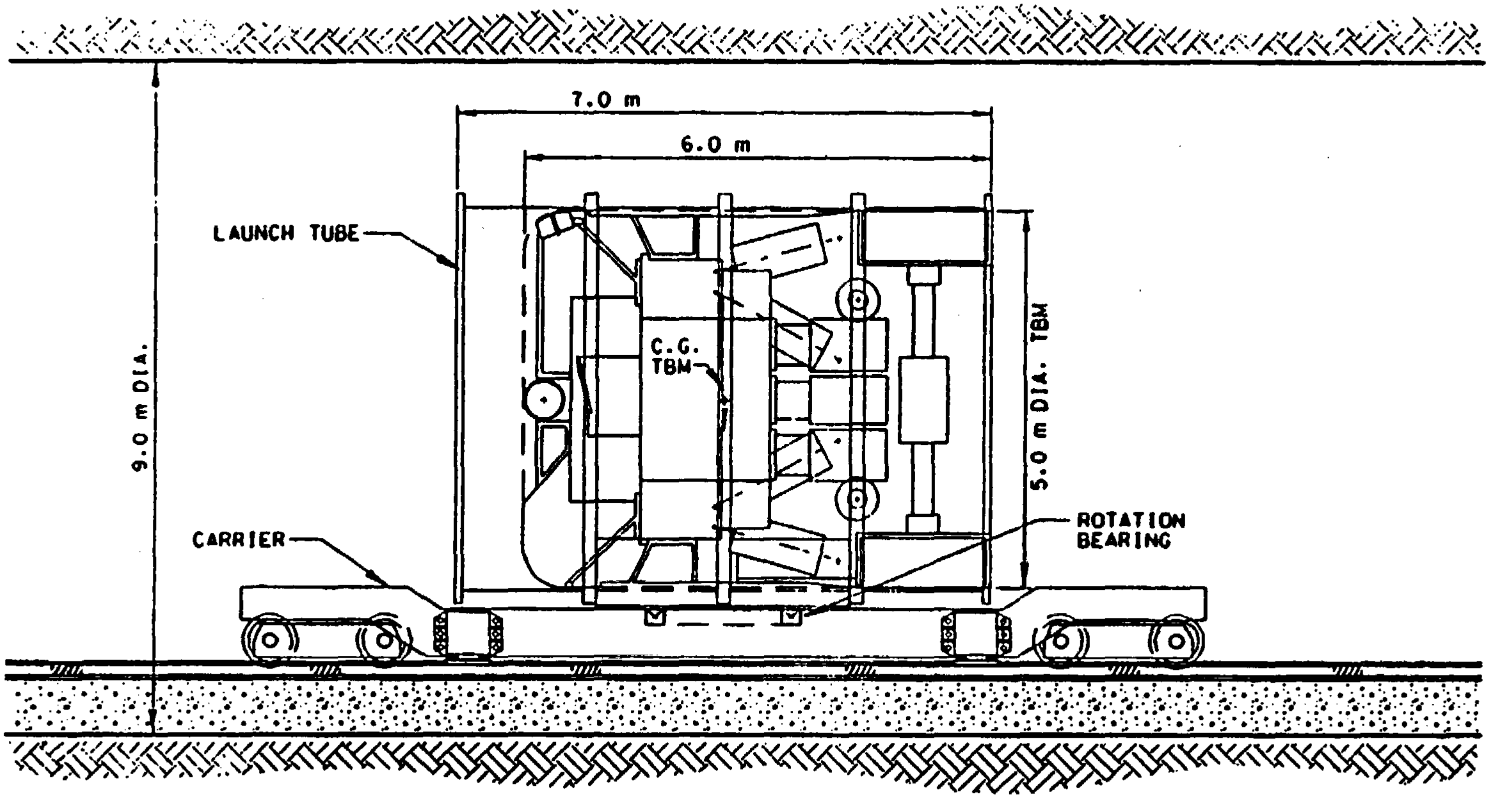
A. The TBM would be moved to the launch site inside a steel cylinder called a "launch tube." While moving, the machine and tube would remain in longitudinal alignment with the various access drifts along the transportation route. The launch tube would be attached to a turntable mounted on top of a specially designed rail carrier. The machine would be positioned inside the tube such that the center of gravity for the TBM coincides with the center of the turntable bearing. This permits stable rotation of the TBM/launch tube assembly on the carrier at the launch site.

B. Prior to moving the TBM into the launch area, a short, truncated cylindrical steel section called a "transition tube" would be positioned on a flat, concrete "grade slab" placed beforehand along the bottom of the radiation door cut-out excavation. The base of the transition tube would be flat and would be outfitted with three hydraulic, vertical positioning jacks. The transition tube would be aligned to the proper line and grade for the emplacement drift.

C. As the launch tube encasing the TBM approaches the launch area, it would be rotated and moved into alignment with the transition tube. Hydraulic outrigger jacks on the launch tube carrier would be used to stabilize and support the weight of the TBM and launch tube. The transition tube and launch tube would then be joined using bolts or clamps and short, 50 to 100 mm thick spacers between the mating ends of the tubes. (The gap occupied by the spacers allows positioning of the launch tube without disturbing the alignment of the transition tube.)

D. A hydraulic cylinder attached to one end of the launch tube is used to extend a primary thrust reaction shoe against the wall of the launch main. The shoe support is locked into position on the slide along which it travels. Two horizontal clamp cylinders attached to the opposite end of the launch tube are then rotated from their transport position and attached to the transition tube using steel links and pins. The clamp cylinders are then extended against the face of the radiation door cut-out.

E. The launch structure is now clamped in place and supported by the seven vertical support jacks. The machine conveyor and necessary trailing floor sections are brought in through the crosscut and connected to the TBM.



NOT DRAWN TO SCALE

Preliminary TBM and Launching Equipment Concepts
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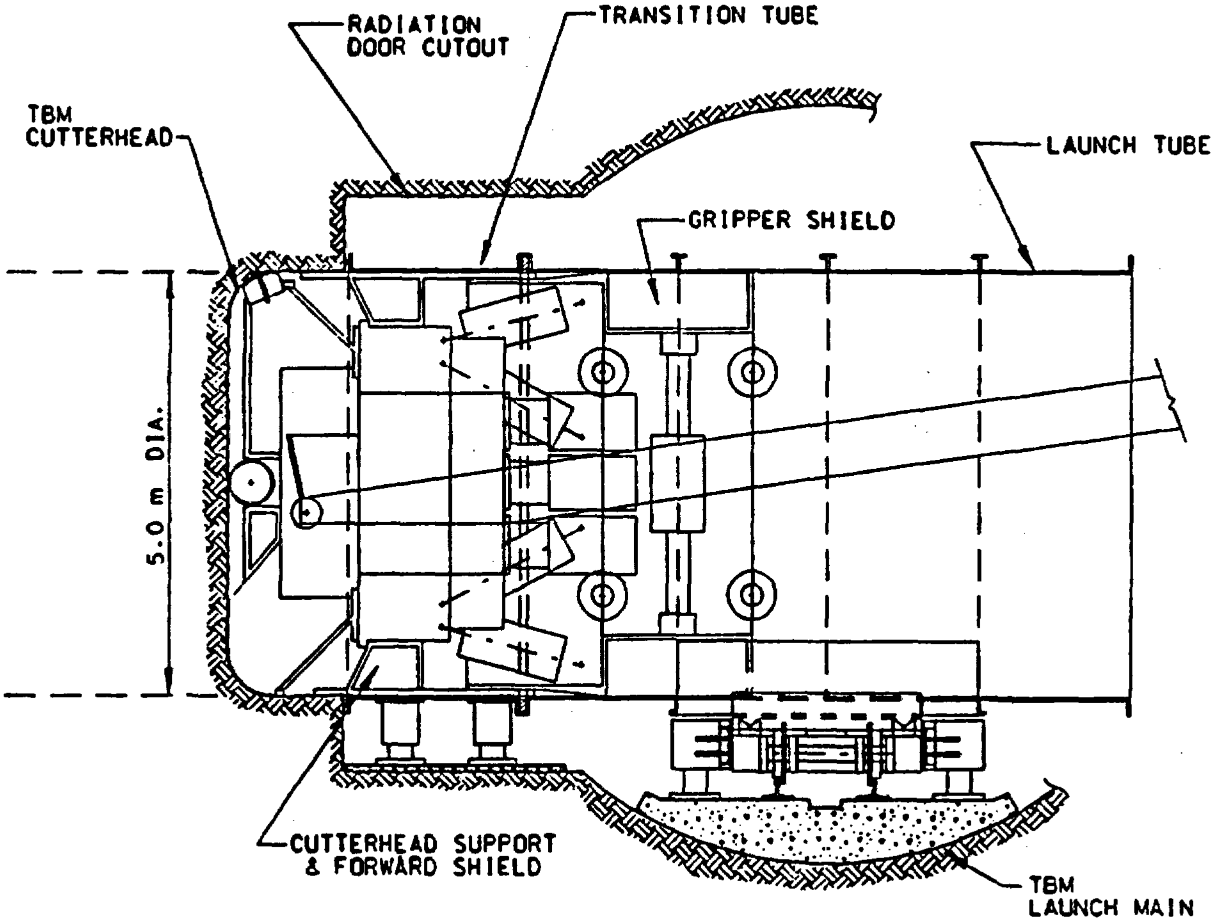
Figure 8.7.1-8. TBM Launch Tube Carrier



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Preliminary TBM and Launching Equipment Concepts
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Figure 8.7.1-9. TBM Launch-Partial Side View

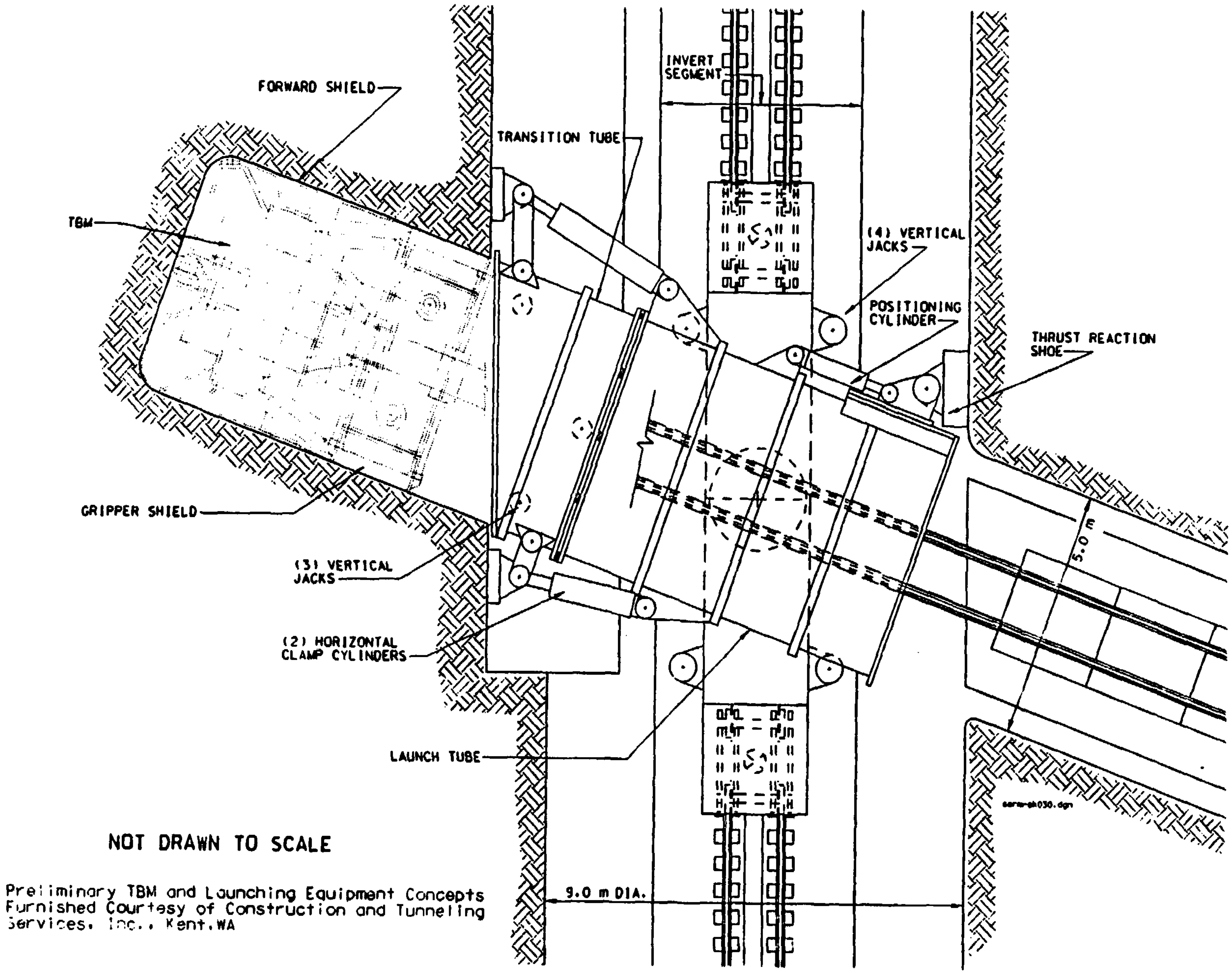


Figure 8.7.1-10. TBM Launch-Plan View

F. The TBM is advanced to the face by lightly gripping the launch tube, but when boring begins, the cutterhead thrust is reacted by retractable "chock" mechanisms mounted inside the tubes. The TBM is advanced forward into the rock in this manner until the grippers pass beyond the end of the transition tube, then extensible struts would be used between the grippers and the last set of chocks until the machine has advanced far enough beyond the initial face to allow pressuring up the grippers without concern for the breaking of rock corners inside the cut-out.

G. After the TBM has advanced sufficiently along the alignment, the remaining sections of the trailing floor are brought from the perimeter main into the service main, and then through the appropriate crosscut and connected to the TBM. The trailing cars ride on rail temporarily laid through the launch and transition tubes. When all of the trailing floor sections are fully in the emplacement drift, the launch structure is disassembled. The transition tube is moved to the next emplacement drift location and the launch tube is moved back into the perimeter main, ready to retrieve the next TBM. A simple support bridge is installed across the launch main to facilitate installation of rail for train traffic into and out of the emplacement drift.

H. As a TBM completes its drive across the emplacement block, it will "hole-out" at the perimeter ventilation main. As soon as the cutterhead is fully into the larger diameter opening, the machine would be backed up slightly, muck would be cleared away from the intersection, and the launch tube would be brought into position on its carrier to retrieve the TBM. A short transition piece would be installed to bridge the bottom of the gap between the end of the emplacement drift and the launch tube, and the TBM would advance into the tube. The tail shield and the machine conveyor would be disconnected from the TBM. The launch tube/TBM assembly would be rotated into longitudinal alignment with the perimeter main and would be moved back to the launch main to begin a new drift. The TBM conveyor, tail shield and the trailing floor cars would be pulled out of the drift and moved out of the way until the TBM is ready to resume boring.

Excavation of the emplacement drifts with the TBMs would be performed in typical, hard rock tunnelling fashion. Muck haulage out of the 900 to 1200 meter long emplacement drifts would be performed using conventional muck trains. Two muck trains would support each TBM operation. Considering the short drift length, and the problems associated with positioning a conveyor belt storage magazine and transfer conveyors in the crosscuts and/or service main, use of a continuous conveyor system to move the muck out of the drifts is considered impractical.

It is envisioned that the muck trains would consist of a locomotive, four each 8 to 10 cubic meter muck cars, and supply cars as needed. In a commercial tunnel, the locomotives would probably be diesel powered. However, due to uncertainties associated with diesel exhaust and its potential effects on waste isolation, electric trolley, or even battery locomotives could be used in this layout since the emplacement drifts are flat-lying and the one-way haul distance is relatively short. A "California switch," a raised, wheeled platform containing two sets of parallel track, with ramps and crossover switches located at each end would be maintained in close proximity to the end of the trailing floor in order to minimize TBM downtime that results when a loaded train leaves the trailing floor and an empty one takes its place.

As the TBM advances, most elements of the permanent ground support would be installed immediately behind the machine, unless a shotcrete or concrete lining is determined to be necessary. Utilities necessary to support the tunneling operation would also be installed as the drift advances. These would include ventilation duct, electrical power and communications cables, a process water pipeline, and a compressed air pipeline.

After the TBM "holes" into the perimeter main, and both it and the trailing floor are removed from the emplacement drift, the cut-out for the radiation door at the end of the drift would be excavated as described earlier. The ventilation duct could then be removed from the drift, since "flow-through" ventilation is available.

Postexcavation construction in the drift could commence following removal of the duct. This work would involve removal of utilities and the excavation rail system, cleanup of the invert, and construction of a cast-in-place concrete floor. It may also include installation of additional ground support or lining. These tasks would be performed in a retreat mode, i.e., in short, distinct reaches in order to maintain the availability of utilities and access rail to the work location, leaving an essentially finished product behind. When the work has been completed back to the service main, an emplacement rail system would be installed on top of the finished concrete. Final installation of various supports, brackets, trackways, or other fixtures necessary to accommodate remote monitoring and instrumentation devices, as well as those items that might be needed to facilitate backfilling or sealing, would then be performed. The drift would be cleaned as necessary, radiation doors would be constructed at each end, and the drift would enter a stand-by mode until turned over to the emplacement operations side of the repository.

Separation of the development and emplacement sides of the repository would be accomplished by erecting "substantial stoppings" that seal against air movement and obstruct equipment passage in the perimeter main, the launch main, and the service main. (It would be desirable to provide for personnel passage through these stoppings to allow an alternate means of escape in case of a fire or other emergency condition as discussed in Section 8.7.2.1). When a new group of emplacement drifts is to be turned over to emplacement operations, new stoppings would be erected at the appropriate location by crews on the development side, then the old stopping would be dismantled by crews on the emplacement side. It may be desirable to design a rolling or movable stopping which could save time and materials as the stopping locations are changed. In this manner, compliance with the separate ventilation systems requirement is maintained.

Inherent in the interim layout is a great deal of flexibility regarding scheduling the turnover of completed emplacement drifts to the emplacement operations side. The panel concept utilized in past work (DOE 1988) required, as a minimum, that development of an entire panel, containing numerous emplacement drifts, be completed before any of the individual drifts inside the panel could be turned over to emplacement operations. The interim layout, on the other hand, could turn over a single drift if necessary-- although it may not be very cost effective to do so because of the work associated with moving the location of the substantial stoppings.

As a general note, it should be pointed out that a key feature that lends credibility to the interim layout is the use of large diameter access drifts, or mains, in conjunction with small diameter emplacement drifts. This concept not only facilitates mechanization of the launching process for starting TBM excavation of the emplacement drifts, it also affords a means of recovering the TBM when the drift is completed and provides a route for moving the machine, basically intact, to the starting location for the next drift. It is conceivable that, with practice, development crews could accomplish the recover-move-launch task inside of a week, given this relative difference in drift sizes and the mechanized launch process described above. Layout concepts that do not provide ample space to perform these tasks could require dismantling the TBMs at the end of each drive, moving individual components to the new launch location, and reassembling the machines in larger diameter openings that have been constructed beforehand by other means. This work could require several months to complete even if the distance moved is only a few hundred meters.

Another key aspect of the interim layout is the flexibility afforded by the parallel service and launch mains. These work together to provide a system that can vary the productivity required of development operations in response to changes in the waste receipt schedule. Additional TBMs can be brought on line if necessary without causing major disruptions to the development scheme.

While it lacks certain optimization, the interim repository development scheme described above is considered to be a realistic scenario, sufficiently flexible to be safely constructed and operated in an efficient, productive manner.

8.7.1.2 Excavated Tuff Handling

As discussed in the preceding section, excavated tuff or "muck" from emplacement drift excavation would be transported in muck cars to a conveyor feeder dump point in the service main. The relatively short length of the emplacement drifts coupled with space restrictions and abrupt corners makes the use of conveyor haulage out of the emplacement drifts both unwarranted and impractical. Muck car haulage is a proven and long-standing method of muck transport in TBM tunnelling operations and is only recently being rejected in favor of conveyor haulage in longer tunnels. In a contract tunneling operation, the additional capital and initial installation costs of a conveyor system can be offset by the operating efficiency inherent in a belt haulage system, resulting in economic viability if the length and configuration of the tunnel are acceptable.

A belt conveyor located in the service main would transport material from the feeder located at the muck car dump point (Figure 8.7.1-7) on the service platform to the South Ramp and then up the ramp to a transfer point located on the surface. Another conveyor system would then carry the excavated tuff to a storage area where it would be stockpiled for potential use as backfill or contoured and topsoiled for permanent disposal.

A scoping evaluation (M&O 1993d) of material handling systems including equipment options and preliminary ranges of throughput rates was made in 1993 for a repository layout similar to the interim layout in this report. The excavated tuff handling system concepts presented here are consistent with earlier conclusions developed in that report. More definitive and up-to-date descriptions that include equipment sizes and throughput rates for the muck handling and storage system will be determined as repository ACD progresses.

8.7.1.3 Transportation of Personnel and Supplies

As mentioned in previous sections, transportation access for personnel, materials and supplies necessary for emplacement and development operations in the interim layout would be via the North and South Ramps, respectively. Transportation requirements of this nature will be much greater in the South Ramp due to increased materials and supplies quantities associated with repository construction on the development side. Pre-ACD conceptual repository designs such as the SCP-CDR (SNL 1987a) equipped the development side shaft with hoisting facilities to provide these services. However, given the integrated rail haulage concept and the relatively short travel distance from the south portal to the development side shaft location in the interim layout, it is judged that personnel and materials hoisting in this shaft are not warranted. This is because transportation times would probably increase due to increased handling times associated with loading/offloading of the shaft conveyance. More definitive evaluations remain to be performed in this area.

At the start of each shift, development crews and other subsurface workers would board a mantrip car(s) (a railcar equipped with several enclosed seating compartments) on the surface and would be pulled by a locomotive to their respective workplaces in the subsurface. Once there, they would relieve crews going off shift at the work area, who would travel back to the surface in the mantrip(s).

For the most part, materials and supplies would be taken underground aboard flatcars pushed by locomotives down the South Ramp, into the service main, and onto the service platform where they would be directed into the appropriate emplacement drift. As mentioned in Section 8.7.1.1, many of the temporary items such as piping, ventilation duct, invert segments, etc., would be reused as construction is completed in the emplacement drifts. Most of the materials transportation in the South Ramp, then, would be permanent ground support or similar items that remain in the emplacement drifts over the long term.

Future ACD efforts will analyze transportation requirements in greater detail, including locomotive and rolling stock fleet requirements, personnel transportation requirements and overall throughput requirements.

8.7.2 Emplacement Operations and Equipment

Preliminary operating concepts for the emplacement side of the repository are presented in the following subsections. The general boundaries of the radiologically controlled area in this side of the repository are discussed. As emplacement and development operations must be conducted concurrently for a number of years, as mentioned in Section 8.7.1, a general philosophy regarding the radiological boundary interfaces between the two sides of the repository is presented. Two preliminary emplacement concepts, introduced in Section 8.5.1.1 and considered by engineering judgment to be applicable to in-drift emplacement of a large MPC based WP, are discussed in greater detail, along with conceptual designs for emplacement equipment to support those operations. A brief discussion of key aspects associated with emplacement drift monitoring, and personnel and supplies transport in the emplacement side is also made.

8.7.2.1 Radiologically Controlled Areas and Boundaries

The entire emplacement side of the subsurface repository, in broad terms, will represent a radiologically controlled area. The overall subsurface boundaries of such an area would begin at the point where subsurface transport casks are loaded at the surface waste handling building (as discussed in Section 7.2), continue to the north portal (M&O 1994m, Key 047), and then extend down the North Ramp, which is proposed as the waste transportation corridor.

An additional subsurface radiological boundary would begin at the emplacement side exhaust shaft surface ventilation plant, continue through the surface air ducting and shaft collar structure, and extend down the shaft to the elevation of the emplacement horizon(s).

On the elevation of the emplacement horizon(s), the entire active emplacement side would be a radiologically controlled area. The boundaries would extend from the emplacement horizon entry point(s) at the north (waste) ramp and the emplacement side exhaust shaft.

During repository development, the boundaries would also begin at the substantial ventilation stoppings shown in Figure 8.8-1 of Section 8.8.2. After all development side construction operations are completed and the stoppings are removed, the boundaries would be extended to the collars and portals of all shafts and ramps leading into the repository.

A key philosophy which must be established early in the repository design process is how and why a radiological boundary would be crossed, as this relates to the normal movement of personnel, supplies and equipment to support the various repository operations. An establishment of such a philosophy is particularly necessary to allow the design of the repository for simultaneous development and emplacement operations.

Using the interim layout, a proposed approach during the phase of simultaneous operations is that the stoppings separating the development and emplacement sides would not be crossed for any reason except during an emergency or accident condition, or to conduct specific pre-approved activities. In other words, crossing the stopping is not considered to be a normal occurrence.

If crossing a stopping were the safest alternative during an accident or emergency situation, establishment of a buffer or safe zone on both sides of each stopping should be considered. The purpose of the buffer or safe zone would be to allow the option for safe crossing in either direction and to provide sufficient space to use as a holding area for personnel until further movement can be coordinated by implementation of an emergency response plan. This aspect is likely to be more critical for personnel crossing from the development to the emplacement side because of radiological safety considerations.

A buffer or safe zone could be created by several means. One alternative could be keeping sufficient distance from the stopping to potentially hazardous operations while maintaining the area in a fresh air stream. A second could be to place a specially designed mobile facility, similar to a refuge station, on either side of each stopping. Mobility of such facilities would be advantageous as they could be moved as the stoppings are repositioned during development operations.

In keeping with the philosophy established by the previous paragraphs, a proposed approach for the transport of personnel, equipment and supplies into the development and emplacement sides is that they would be separated at all times. Each side would therefore have its own transport routes. Transport routes are discussed further in Section 8.7.1.3 for the development side and Section 8.7.2.4 for the emplacement side.

A key point to be established for the emplacement side will be the coordination of waste transportation activities with personnel and supplies transport through the North Ramp and on into the emplacement area. Several ways to address this could be the establishment of personnel and materials transport "time windows." Such time windows could be established when waste transportation operations would not be in a sequence where personnel would come in contact with a transport cask in route to the emplacement area or during some other critical phase of the emplacement sequence. This may be a readily feasible option for two reasons. Due to the size of the WPs being considered in ACD, the daily volume of WPs to be emplaced will be low. The number of personnel to be transported into and out of the emplacement area would also be low because the philosophy presented above would help to ensure that only the personnel absolutely essential to the emplacement side operations would be present in the emplacement area at any time during normal operations.

Although not addressing personnel transport, another option may be to transport a sufficient stock of materials and equipment to underground warehousing areas in the emplacement side on a shift where waste transportation operations will not be conducted. Such a shift could be a regularly scheduled maintenance shift.

Additional work to further define radiological boundaries and control measures during the above described phase, as well as later phases of repository operations, will be performed as ACD progresses.

8.7.2.2 Subsurface Waste Emplacement Operations and Monitoring

The emplacement operations concepts described in the following subsections have been developed without the benefit of thorough evaluations relating to personnel radiological safety, including analysis of the radiation environment inside the emplacement drift, and in the waste handling main with and without the radiation shield door in an open position. The concepts are very conceptual and must be evaluated in much greater detail as ACD progresses.

8.7.2.2.1 Emplacement on Wheeled Cart Using Locomotive

As described in Section 8.5.1.1, this in-drift emplacement concept consists of an MPC based WP permanently mounted on a steel-wheeled cart that rolls on rail laid in the invert of a 5.0 meter diameter emplacement drift.

It is assumed that the WP and its emplacement cart would be inserted into a transport cask in a hot cell located in the waste handling building on the surface before being moved away from the waste handling building. The transport cask could be designed to reduce surface dose radiation exposure to "stand-beside" limits.

Figure 8.7.2-1 portrays the steel cask concept that is envisioned. It would be outfitted with an outer set of steel wheels that facilitate loading the cask onto a transport carrier and offloading of the cask onto an emplacement platform situated at the mouth of an emplacement drift. The interior of the cask would be equipped with a device to secure the WP/cart during transport and a self-contained mechanism capable of offloading the WP/cart assembly into one end of an emplacement drift.

The transport cask would be moved to the subsurface on a specially designed, but relatively simple rail carrier. The carrier would be coupled to a locomotive and the pair would travel down the North Ramp to the waste handling main, i.e., that portion of the TBM launch main that is located on the emplacement operations side of the repository. Access into the waste handling main is gained by first entering the service main (the portion on the emplacement side) at the bottom of the North Ramp, then reversing direction and traveling north in the service main through the curve that transitions into the perimeter main, then reversing direction once again and entering the waste handling main, probably through a set of doors that control access. If necessary, that portion of the service main not used as a travelway might be equipped with an energy arrestor used to stop the transport vehicles in the unlikely event of a "runaway" on the North Ramp. This transportation route minimizes the possibility of a runaway colliding with an in-process emplacement operation, as the final approach is on an uphill grade following a reversal of direction.

An alternative means of accessing the waste handling main from the surface would be via the potential waste transport connector drift shown on Figure 8.6.3-1 that connects the North Ramp extension to the waste handling main.

An emplacement platform situated in the waste handling main would be used to facilitate offloading of the transport cask and insertion of the WP into an emplacement drift. The locomotive would back the transport cask carrier against the edge of this platform. Hydraulic outrigger jacks and a sliding carriage on the carrier would then be used to position the cask in such a manner that it could be pulled off of the carrier and onto the platform. A turntable mounted in the emplacement platform would then rotate the cask into alignment with the emplacement drift as shown on Figure 8.7.2-2.

Up to this point, all operations could be conducted without unusual concerns for worker radiation exposure, so long as the transport cask has been designed to "stand-beside" standards. The actual opening of the cask, and insertion of the WP into the emplacement

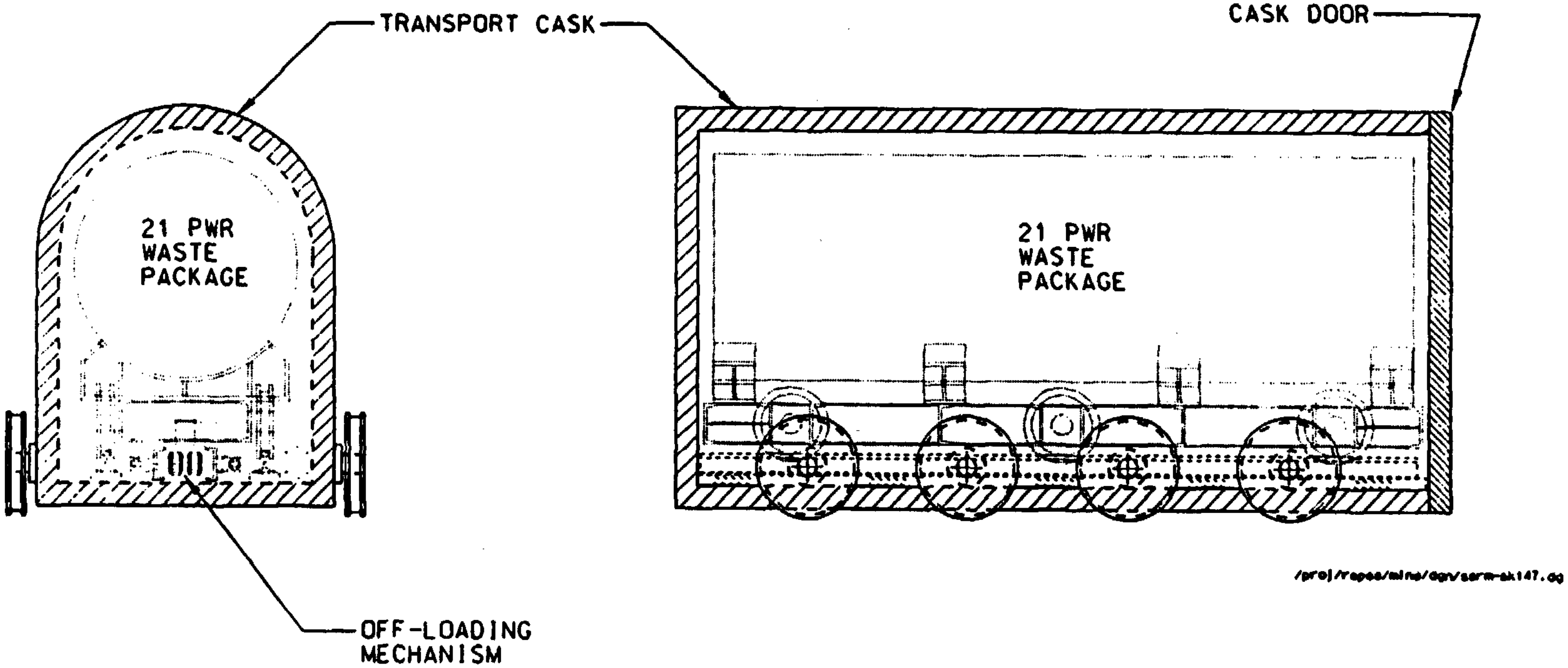


Figure 8.7.2-1. Subsurface Transport Cask Concept

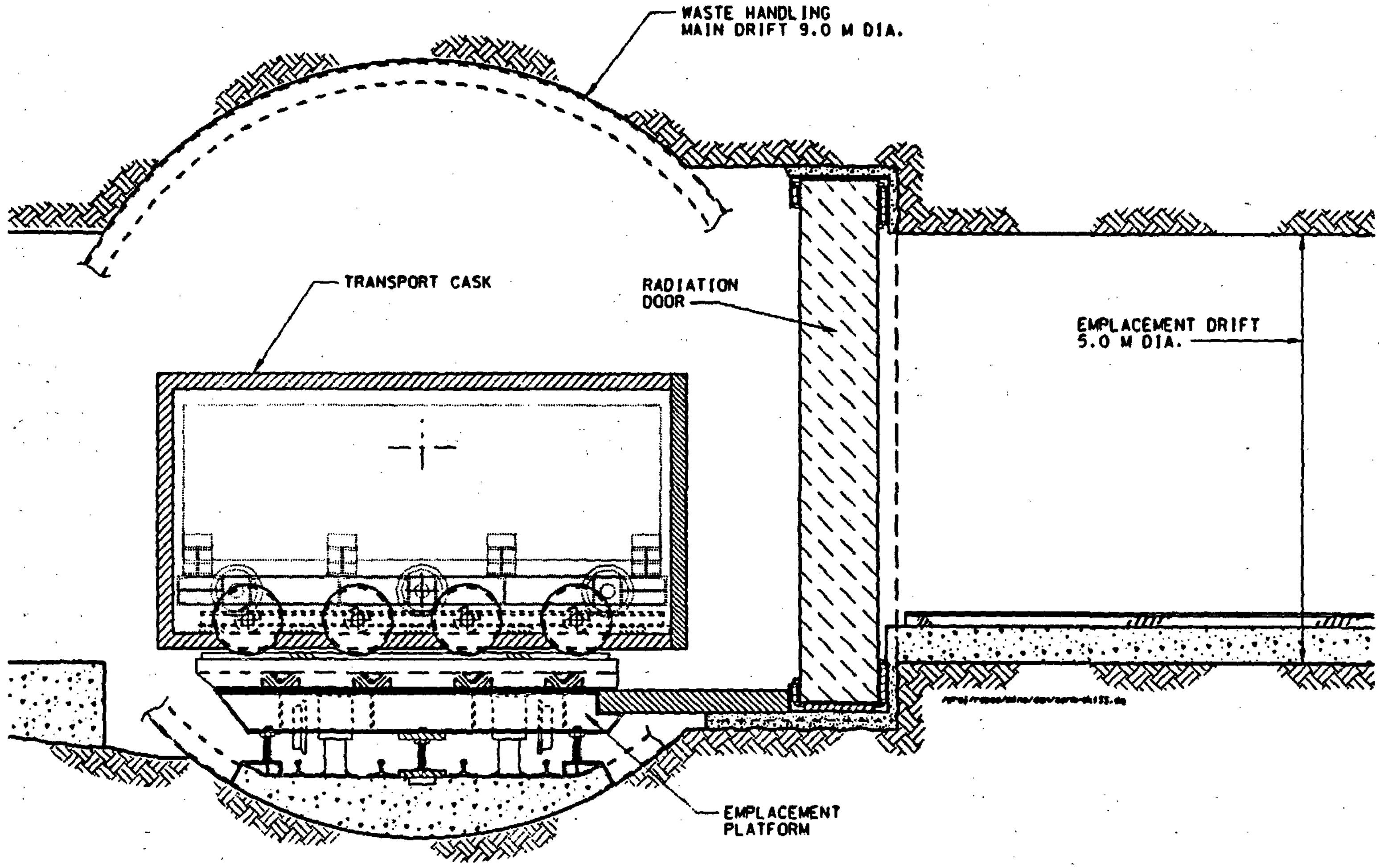


Figure 8.7.2-2. Cask Aligned with Emplacement Drift

drift, would result in exposure risks for anyone positioned in-line with either the drift or cask openings. Therefore, workers and operators would position themselves ten to twenty meters away from the emplacement platform, probably inside of a portable, shielded enclosure (shielded for purposes of offering an additional level of protection beyond that afforded by being located out of line with the radiation sources) prior to opening either the cask or the sliding radiation door situated across the mouth of the emplacement drift. All operations involved with the actual emplacement of the WP would be conducted remotely from within the shielded enclosure.

The remotely guided, video monitored steps involved with conducting the actual emplacement operation are envisioned as follows:

A. With the transport cask centered on the emplacement platform, the radiation door on the emplacement drift would slide open. As the door assumes its full open position, it pulls a structural transition piece into place that is used to bridge the gap between the platform and the invert rail situated just inside the emplacement drift.

B. The transport cask would be moved toward the drift, on the emplacement platform, until resting its forward wheels fully on the transition piece. The door on the cask would then be opened, as it is now in an overlapping position with the end of the open drift door, and thereby afforded a substitute layer of shielding.

C. With its door open, the transport cask would be moved forward once again, pushing a short section of sliding rail on top of the transition piece forward until mated firmly with the rail in the emplacement drift and the rail inside of the cask. The cask would then be secured to prevent further movement.

D. The self-contained mechanism inside of the cask used for moving the WP into the drift would then be activated. This device would be capable of pushing the package fully into the end of the drift and would activate a "stop" or brake on the emplacement cart to hold it in position. (The mechanism would also be designed to pull packages into the cask, if necessary, for performance confirmation, retrieval, or other purposes.) After pushing the WP into the drift, the mechanism would be withdrawn into the cask. Figure 8.7.2-3 shows the WP being moved out of the transport cask, into the end of the drift.

E. With the WP "parked" just a meter or so inside of the drift, the cask would be withdrawn fully onto the emplacement platform, pulling the sliding rail on top of the transition piece back into a retracted position.

F. The radiation door on the emplacement drift would then be closed, allowing workers to resume non-remote operations. The door on the cask would be closed and the cask would be rotated on the platform into longitudinal alignment with the main drift as shown on Figure 8.7.2-4. The cask would then be loaded back onto the rail carrier. The carrier would lower itself back onto the rail and the locomotive would pull the empty cask back to the surface to pick-up another WP.

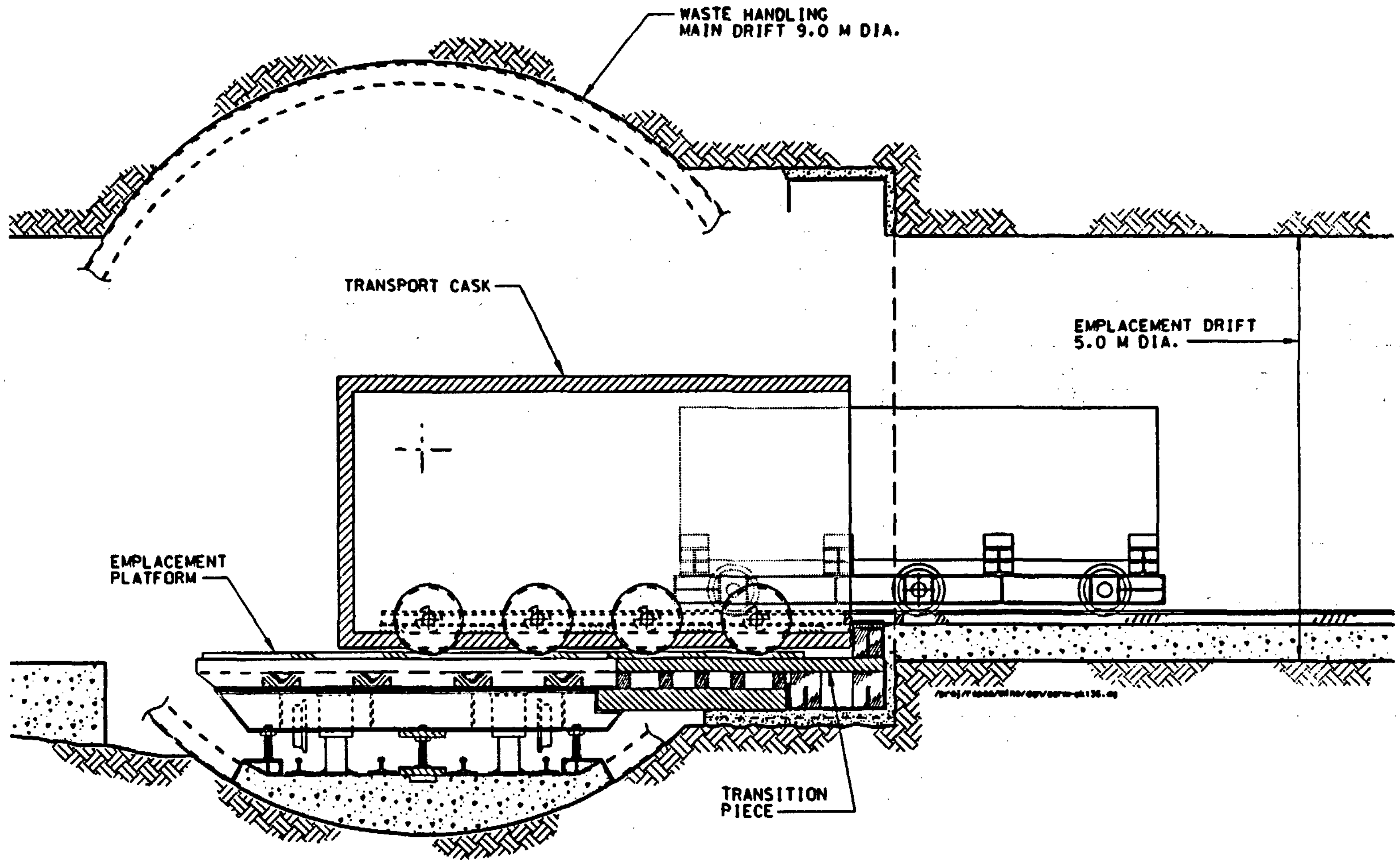


Figure 8.7.2-3. Waste Package Being Pushed into Emplacement Drifts

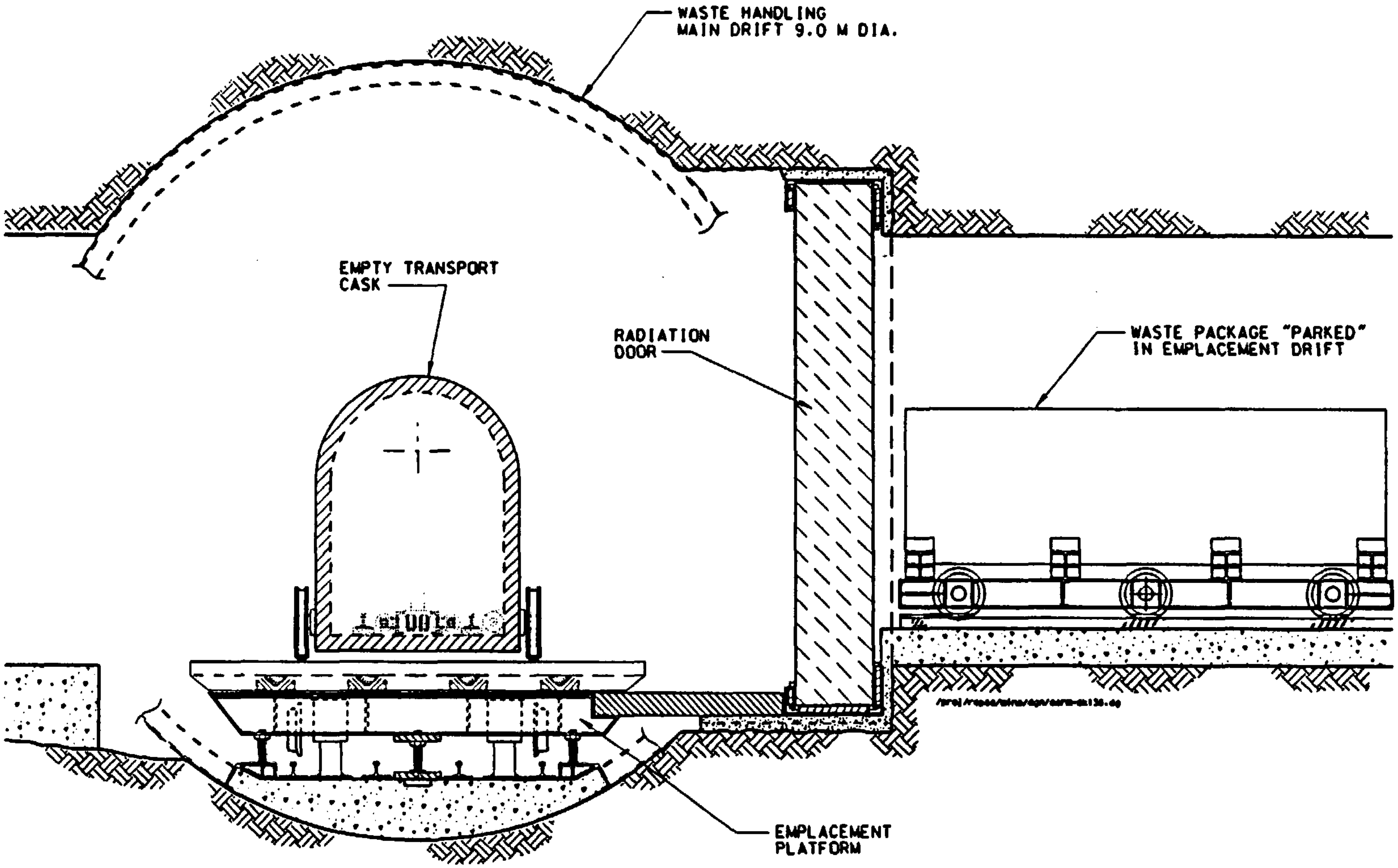


Figure 8.7.2-4. Empty Cask Rotated for Return Trip to Surface

G. A remotely operated, battery-powered locomotive used for pushing the WP to its emplacement position in the drift would then be readied for operation. (While the cask is on the turntable, this locomotive would be parked in a stand-by position on a non-rotating extension of the emplacement platform located opposite from the cask delivery area.) The locomotive would be mounted on a fixture that resembles the floor of the transport cask in order to properly fix the vertical position of the locomotive wheels relative to the rail in the emplacement drift. Using the same mechanism designed for moving the transport cask on and off of the platform, the locomotive would be positioned on the platform turntable and would be rotated into alignment with the emplacement drift. Workers would re-enter their remote enclosure and the drift door would be reopened.

H. By completing the same basic movements on the platform as described above for the transport cask, the locomotive would be directed into the drift and would couple to the WP. The emplacement cart stop mechanism would be deactivated and the locomotive would push the WP/cart to its intended emplacement location in the drift as shown on Figure 8.7.2-5. The radiation door would be closed. Upon reaching the emplacement position, the locomotive would activate the stop mechanism on the cart and would decouple from it. The locomotive would then return to the emplacement platform and the radiation door on the drift would close.

I. The emplacement crew would resume non-remote operations in the main drift to prepare for the next WP. The emplacement locomotive would be repositioned in its stand-by location on the emplacement platform.

For efficiency of operations, it is envisioned that the emplacement platform would be positioned only one time for each emplacement drift, and that emplacement of all of the packages for that drift would be completed before moving the platform to the next drift location. This concept is not mandatory but would eliminate the downtime that would result from numerous platform relocations.

Moving of the emplacement platform would be accomplished by lowering the vertical positioning jacks so that the weight of the platform is transferred onto steel wheels that roll on rail laid on the invert of the main drift. The platform would be towed to the next emplacement drift in line and would be repositioned, using survey index points established during construction of the emplacement drift as a reference base. These points would allow the platform to be located at the precise location necessary for horizontal and vertical control of the emplacement operation. Vertical positioning jacks would be used to establish the precise rail elevation necessary, then the platform would be mechanically fixed in position to relieve the hydraulic pressure in the cylinders. The transition piece mentioned above would be utilized once again, but would probably require a slight amount of height adjustment, using metal shims or similar methods, to allow the platform, cask, and locomotive to be properly mated with the rail in the emplacement drift. The portable shield enclosure and the device used to open and close the radiation door would be moved ahead prior to moving the platform.

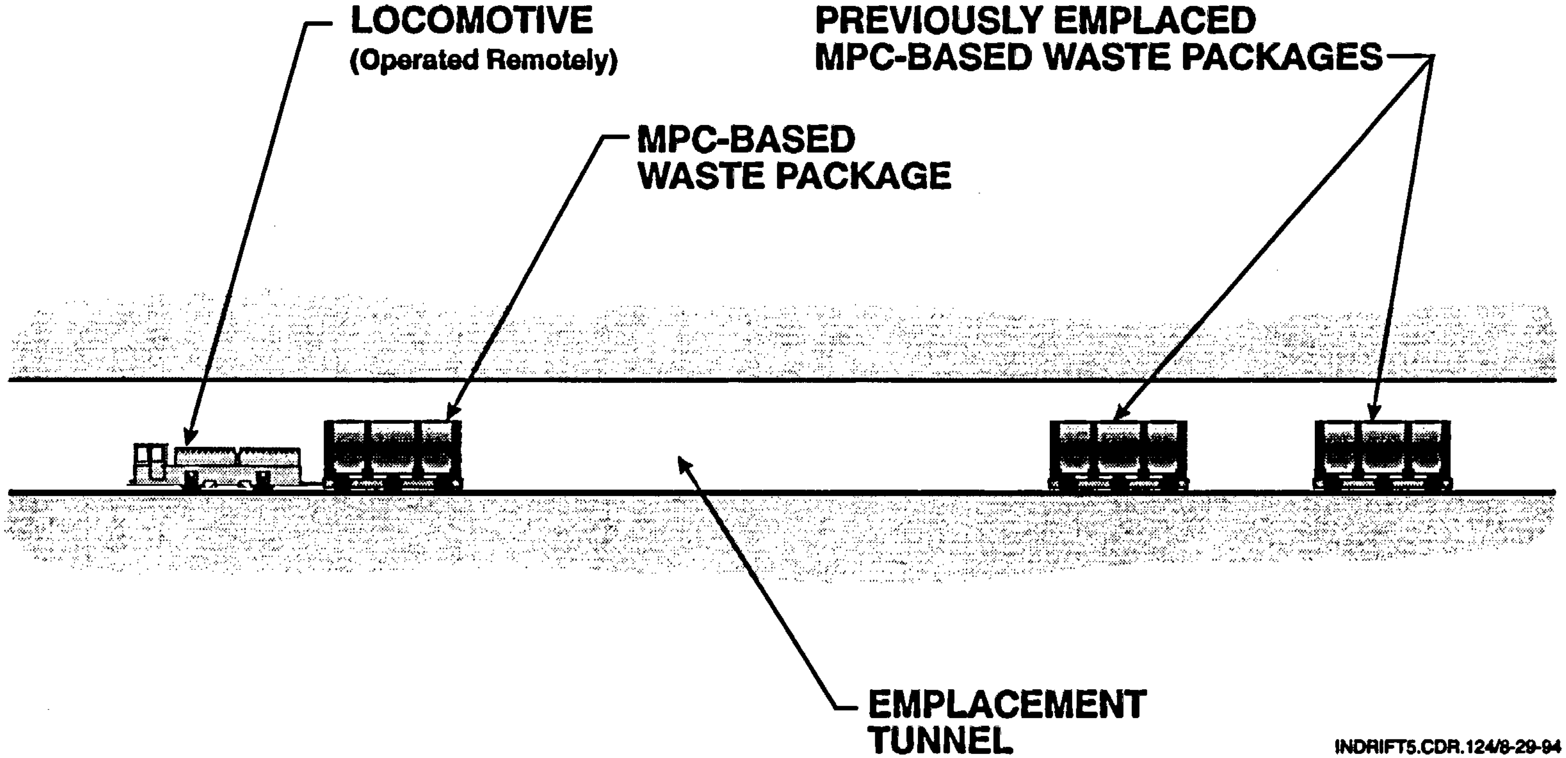


Figure 8.7.2-5. Locomotive Pushing Cart Mounted Waste Package to Emplacement Location

Emplacement operations under the interim layout concept would proceed sequentially, drift by drift, from the north end of the layout toward the south. If more than a single emplacement operation is needed in order to sustain the waste receipt schedule, then some of the crosscuts connecting the service and launch mains would be excavated to a larger profile during development in order to provide additional points of access from the service main for the waste transport vehicles. This adjustment to the basic concept would be necessary because the emplacement platform blocks access to that portion of the main drift that is located south of the emplacement operation. Chances are good, however, that a single emplacement system designed to operate more or less as described above could maintain a sufficient rate of emplacement. Current projections are that a total of approximately 12,000 packages will be emplaced at a peak rate of just over 500 packages per year, or approximately 2 packages per day (M&O 1994m, Key 041). A key aspect of the concept described above that would allow the system to work with a minimum number of transport vehicles is the "divorcing" of the transport function from the actual emplacement function. This allows the cycle times for the transport and emplacement operations to overlap, and simplifies the range of functions that each piece of equipment must be capable of performing.

Future ACD efforts will investigate the practicality of performing the entire subsurface portion of the emplacement operation remotely. Remote systems are already used to perform many of the more complicated tasks described in the discussion of emplacement operations presented above. It may be that consideration of ALARA principles result in further application of remotely operated concepts, perhaps in conjunction with different emplacement/waste handling schemes.

A potential alternative might be to eliminate the emplacement platform, bringing a rail mounted WP into the service main, through the appropriate crosscut and then through the radiation door and straight into the emplacement drift without having to go through the offloading and rotation tasks associated with the platform concept as described earlier. This and many other concepts remain to be evaluated as the ACD effort progresses.

8.7.2.2.2 Emplacement on Raised Pedestals Using Gantry

This concept is similar to that described in the preceding section, except that the WPs do not require a permanent cart to facilitate the emplacement and retrieval processes. Rather, a gantry type mechanism would be used to move the WPs inside the emplacement drift and for lowering them onto pedestals in predetermined emplacement positions. The gantry/pedestal concept requires a larger drift cross-section than is required using the cart/locomotive and involves more complex remote handling movements inside the emplacement drift but it offers the ability to thermally manage the WPs by adjusting their position inside the drift during the preclosure years without removing any packages from the drift.

Gantries are commonly used in many heavy industrial applications to lift and move large, heavy objects. They are often custom designed to fit a specific application. In the underground construction industry, gantries are often used to advance, set, and support large and heavy concrete forms. Examples of two preliminary conceptual gantry designs developed to emplace and move WPs in the Center-In-Drift concept are shown in Figures 8.7.2-6 and 8.7.2-7.

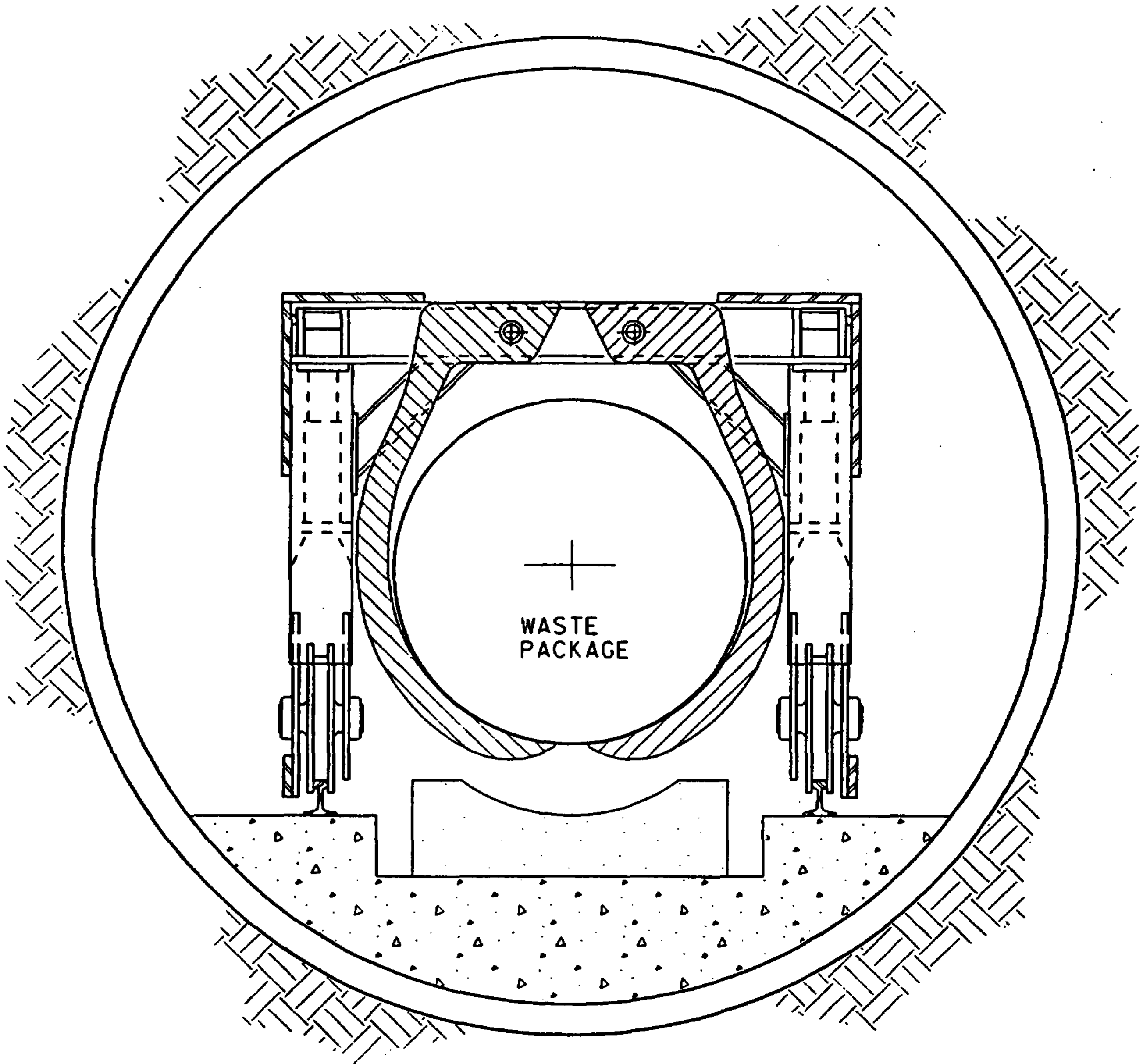
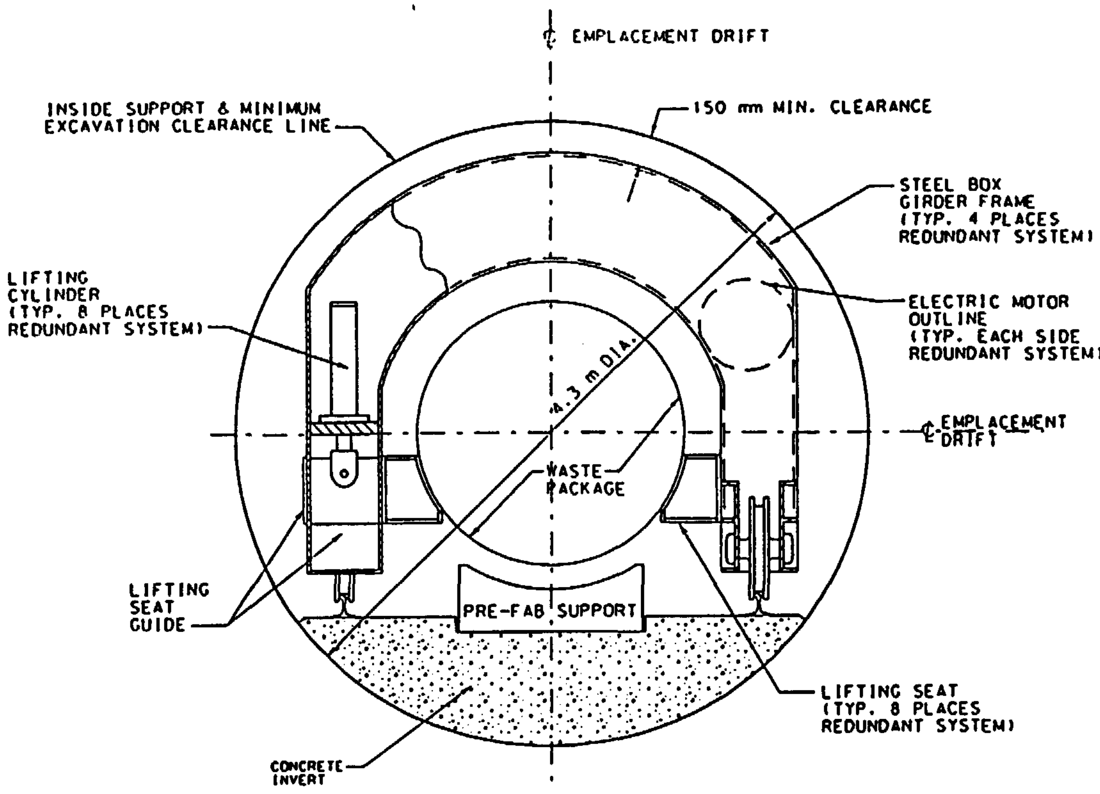
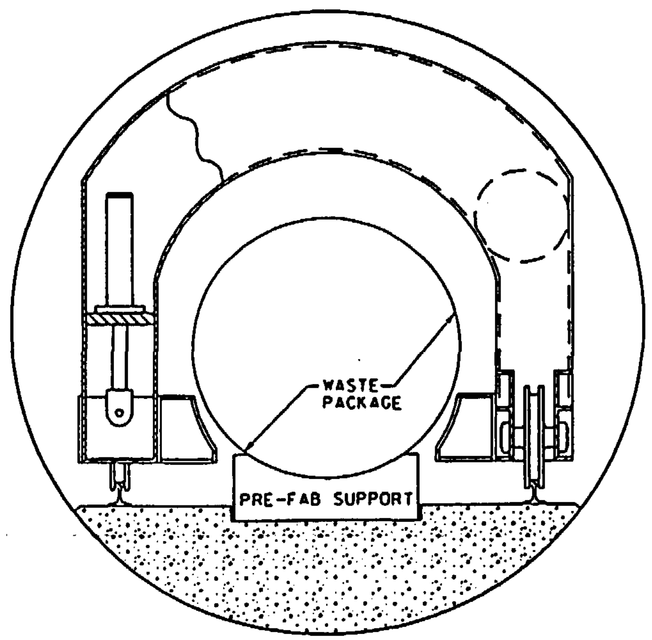


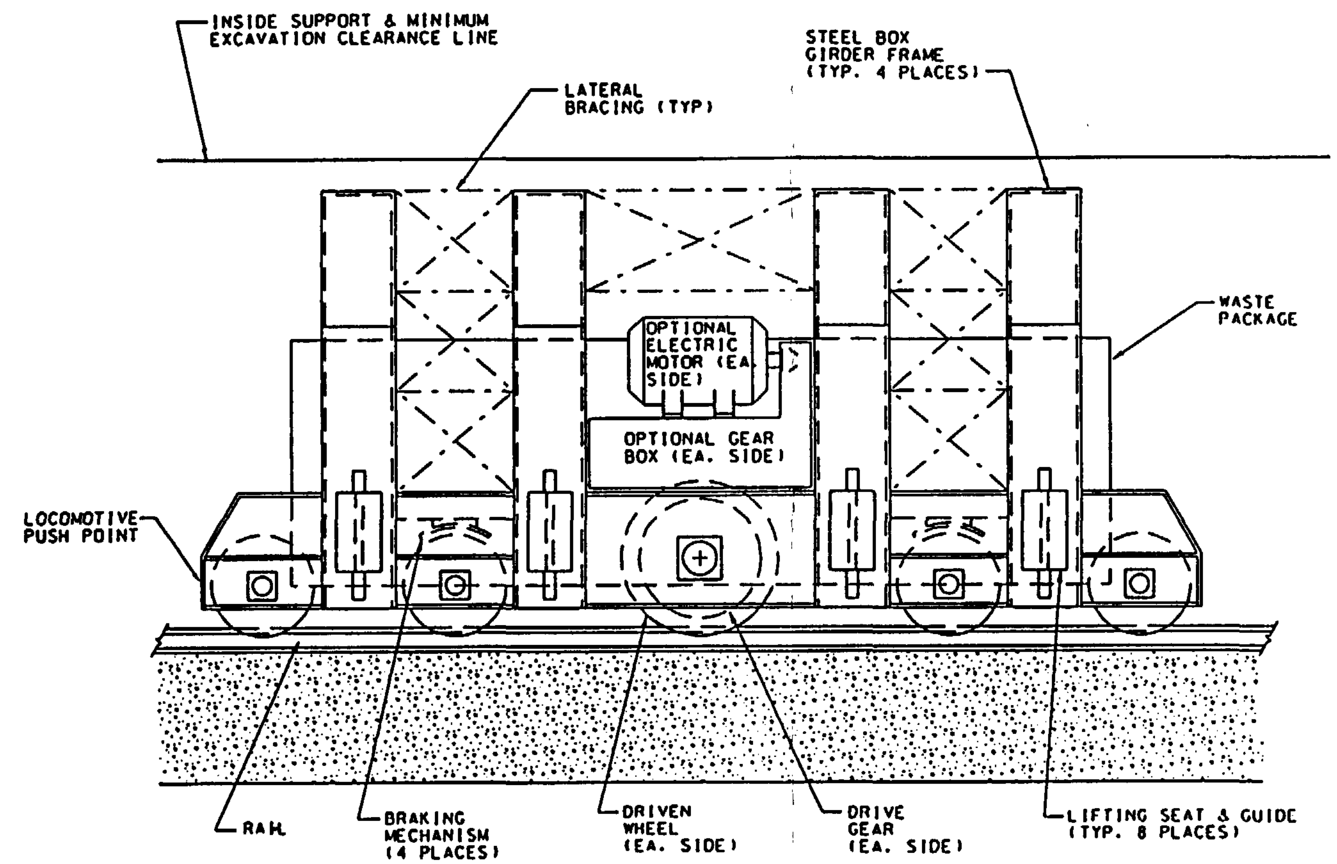
Figure 8.7.2-6. Conceptual Gantry Concept



END ELEVATION
(FULLY RAISED POSITION)



END ELEVATION
(FULLY LOWERED POSITION)



SIDE ELEVATION
(FULLY RAISED POSITION)

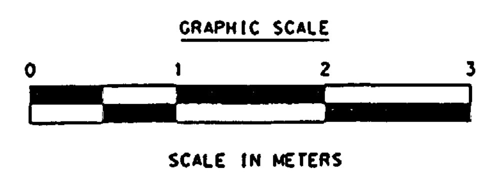


Figure 8.7.2-7

ALTERNATIVE WASTE PACKAGE LIFTING GANTRY WITH OPTION FOR SELF-PROPULSION

DRAWN	DESIGNED
R REGAN	D EINARSON
	CAD FILE SSRM-SK097.DGN

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Figure 8.7.2-7 shows a design concept for a self-propelled gantry. The gantry is designed to lift a WP off of a temporary transport cart, which would resemble an emplacement cart in the permanent emplacement cart option. This lifting operation would occur in the emplacement drift entrance, just inside of the radiation door. A WP in the horizontal position is lifted from its lower quadrant by lifting seats attached to guides mounted integrally into the frame of the gantry. Slots in the frame guide the lifting seat/guide mechanism. Although not shown in Figure 8.7.2-7, the guide mechanism would be equipped with suitable linear-bearing assemblies to prevent binding of the guide.

The mechanics of the lifting mechanism will exert large, opposing, horizontal forces into the gantry frame. The large, horseshoe-shaped, steel box girders, provide the strength and rigidity to resist such forces without significant lateral deflections which would be detrimental to the rail on which the gantry rides.

Lifting jacks are incorporated to raise and lower the guide seat mechanisms. The jacks could be hydraulic cylinders, or alternately, acme-thread screw jacks equipped with a swivel. Since the jacks must raise simultaneously with relative precision, screw threaded jacks powered by a precision drive source may be a preferred alternative. For simplicity, Figure 8.7.2-7 portrays hydraulic cylinders, but future conceptual sketches will be developed which incorporate screw jacks and their drive mechanism.

The gantry would be propelled at a low acceleration rate and slow speed, probably in the range of 0.5 to 1 m/s, by an electric motor which drives a gear box. The slow speed and acceleration will allow a reasonably sized motor to be used and would reduce the potential for accidents during the transportation operation. To provide speed variation, the electric motor could be DC, or AC with variable-frequency drive. The final gear in the gear box is a drive gear which is integrally mounted to a driven wheel, as shown in Figure 8.7.2-7. The driven-wheel propels the gantry. This drive arrangement has some similarities to electrically powered locomotives. Braking mechanisms are provided, and would be designed to stop the gantry without aid of the drive system components. Drive system components could also provide dynamic braking capability.

Conceptual design features incorporated into the gantry shown in Figure 8.7.2-7 have a three-fold purpose: reliability, total redundancy of critical components, and robust construction as discussed below. First, the lifting principle incorporated into the gantry concept is designed with reliability in mind by using a minimum of moving parts as well as single direction, well-defined, ranges of motion.

Total redundancy of critical components is provided as indicated in Figure 8.7.2-7. For example, four lifting points with associated lifting mechanisms are required but eight are provided. In addition, the outer four lifting mechanisms would be designed to operate from a separate control system from the inner four. Similarly, two support frames consisting of steel box girders are required but four are provided. The gantry drive system consists of duplicate electric motor, gearbox, drive gear, and driven wheel components. Again, separate control systems for each drive system would be included, and each drive system would be designed to propel the gantry on its own. Redundant support wheels are also provided.

The gantry shown in Figure 8.7.2-7 is of robust construction where the steel box girders (constructed of heavy plate sections), associated bracing, and deep wheel support girders will provide considerable multi-axis rigidity in the gantry frame.

The gantry is also conceptually designed to recover from failure modes in several ways. Redundancy in drive system and lifting components would minimize the chance for crippling failures, but nevertheless, several features will aid in recovery. In failure of both drive systems, or their power source, recovery can be accomplished by using a conventional battery-powered locomotive as an alternate prime-mover. The locomotive would attach itself by a simple mechanism to the gantry frame in the locomotive push point position shown. The gantry could then be pushed into the drift to complete the emplacement operation or could be towed out of the drift.

Redundancy built into the lifting mechanisms would minimize the possibility for a crippling failure mode which would cause the WP to be dropped. However, if a package could not be raised for some reason, the bottom of the box girder will act as a lower stop for the lifting seat guide. The gantry could be moved out of the drift with the lifting seat guides in the fully lowered position, similar to that shown in Figure 8.7.2-7, and the WP resting on them; although, the pre-fabricated pedestals would have to be moved out of the drift to do this.

8.7.2.3 Emplacement Drift Monitoring and Instrumentation

Specific emplacement drift monitoring and instrumentation requirements have not been defined at this time regarding the frequency and nature of inspections and tests that are important. Given the hostile radiation and thermal environment that will exist adjacent to unshielded WPs emplaced in an open emplacement drift, equipment used to monitor and obtain measurements inside the drift must be robust. Remote systems will need to be developed that can easily install and remove this equipment so that maintenance and calibration can be performed. A lightweight monorail beam or similar trackway might be suspended from the crown of the emplacement drift, extending throughout, and used to support and guide a device that performs the inspection functions. Alternatively, gantry emplacement concepts might use another lightweight gantry that carries the monitoring and instrumentation equipment throughout the emplacement drift. These and other concepts, in addition to the functional requirements for this subsystem, remain to be examined as ACD progresses.

8.7.2.4 Transportation of Personnel and Supplies

Although this particular aspect has not received much attention at this point in repository ACD, requirements for transportation of personnel and supplies to support emplacement operations should be less than the total number of trips necessary relative to development operations.

As mentioned in Section 8.7.2.1, a key element to be considered for the emplacement side will be the careful coordination of waste transportation activities with personnel and supplies transport through the North Ramp and on into the emplacement area.

This and other considerations will be more fully evaluated as ACD progresses.

8.8 SUBSURFACE VENTILATION

The basic function of the repository subsurface ventilation system for the potential repository is to control air movement (quantity, quality, and direction of airflow) to meet the needs of repository underground activities including:

- Initial repository construction or development
- Simultaneous development and waste emplacement
- Emplacement after completion of construction
- Postemplacement (caretaker) repository operations.

This section is intended to provide a preliminary discussion of air distribution concepts, potential airflow requirements, and some typical results from modeling of the ventilation system. It focuses primarily on the ventilation concepts for development and emplacement. Discussions of preliminary considerations for emergency and escape are also provided. Considerations of retrieval ventilation during the postemplacement (or caretaker) period are addressed later in Section 8.12.5.

General airflow distribution strategies for a ventilation system are governed by factors including safety, cost, flexibility, and development sequence. A primary concern is safety. The repository design requirement stipulated by 10 CFR 60.133(3)(g) dictates that the underground facility ventilation system shall separate the ventilation of excavation and waste emplacement areas. Although specific definition of the separate system is not given in the CFR, the main purpose of the requirement is to limit potential radiation exposure. To meet this requirement, proper arrangement of the primary air intake and exhaust for development and emplacement areas requires consideration. The Repository Underground Ventilation Concepts (M&O 1993j) analyzed several alternatives regarding separate ventilation. It indicated that planning two entirely independent ventilation systems is a favored scheme for safety concerns.

The repository ventilation is arranged to maintain two separate airflow systems. One system provides air for the development of the repository while the other provides air for the waste emplacement operations. Each system has its own primary intake and exhaust openings to the surface for the supply of fresh air and exhaust of return air. Underground openings between the two ventilation systems are sealed with bulk-heads (air stoppings) or air locks (double air doors).

The two completely independent ventilation systems basically have no operational impacts on each other. For balancing the network, fan coordination, design and construction of ventilation control devices, independent systems are simpler and more reliable than two systems with common intake or exhaust airways. The pressure difference of the ventilating air between the two systems can be designed in such a way that the unavoidable air leakage always moves from the development to the emplacement area. Each system will have continued functions during normal operations or when accident conditions occur in the other.

For example, if areal or major reversals of airflow were necessary for one system due to a fire emergency, the other system can remain unchanged and operations are not affected.

More importantly, personnel under such emergency conditions have an extra choice to escape by entering the other system through the strategically placed air locks. A disadvantage of this scheme is that simultaneous development and emplacement are possible only after construction of four major access openings to the surface are completed. However, with the interim layout, two of the openings (ramps) would be completed as a part of the ESF.

Figures 8.8-1 and 8.8-2 show (diagrammatically) the general method that is envisioned for air flow distribution for the development and emplacement areas, respectively, using the interim repository layout concept. The configuration of the ventilation network for other layout concepts would vary according to the specific layout that might be used and the development and emplacement operational scenarios that might be employed. The ventilation system would be designed so that all air leakage between the two systems is from the development area to the emplacement area. This pressure differential is created by using a primary forcing, or positive pressure main fan(s) in the development intake (South Ramp) and using exhausting, or negative pressure main fan(s) installed at the collar of the emplacement exhaust shaft. With this type of arrangement, the pressure differential forcing air leakage from the development area to the emplacement area always exists, even if the ventilation pressure supplied by one of the systems is interrupted. Since the development and emplacement areas are ventilated separately, discussions of the two independent systems are made separately in the following two sections.

8.8.1 Development System Quantities and Distribution Concepts

The development side ventilation system will support initial construction and continuous development after waste emplacement begins.

Initial construction covers the excavation prior to waste emplacement. Due to potential scheduling constraints, it would not be desirable to construct the entire repository before waste emplacement begins. To facilitate simultaneous construction and emplacement and maintain separate ventilation circuits, the initial development of the repository is needed to provide excavated underground area and sufficient major openings to the surface. This initial excavation can proceed in much the same manner as the development of a comparably sized mine, and can be supported by a single ventilation system. The ventilation considerations for this stage will be governed by conventional underground ventilation requirements, such as items stated in 30 CFR 57, 29 CFR 1926 and CAC Title 8. [RDRD 3.7.5.B.7]
[RDRD 3.7.5.C]

Simultaneous development and waste emplacement operations will occur when minimum required initial excavation is completed. As shown on Figure 8.8-1, the development operation is in advance of the emplacement operation from north to south. Although heat released from WPs will affect ventilation of the emplacement area, it will have little effect on the development system. This is because the air flows of the two ventilation systems are independent and conduction is the only means for heat exchange between the two systems; when there is insufficient time for conductive heat to reach the advancing development areas, the rock temperatures in development airways will not be affected.

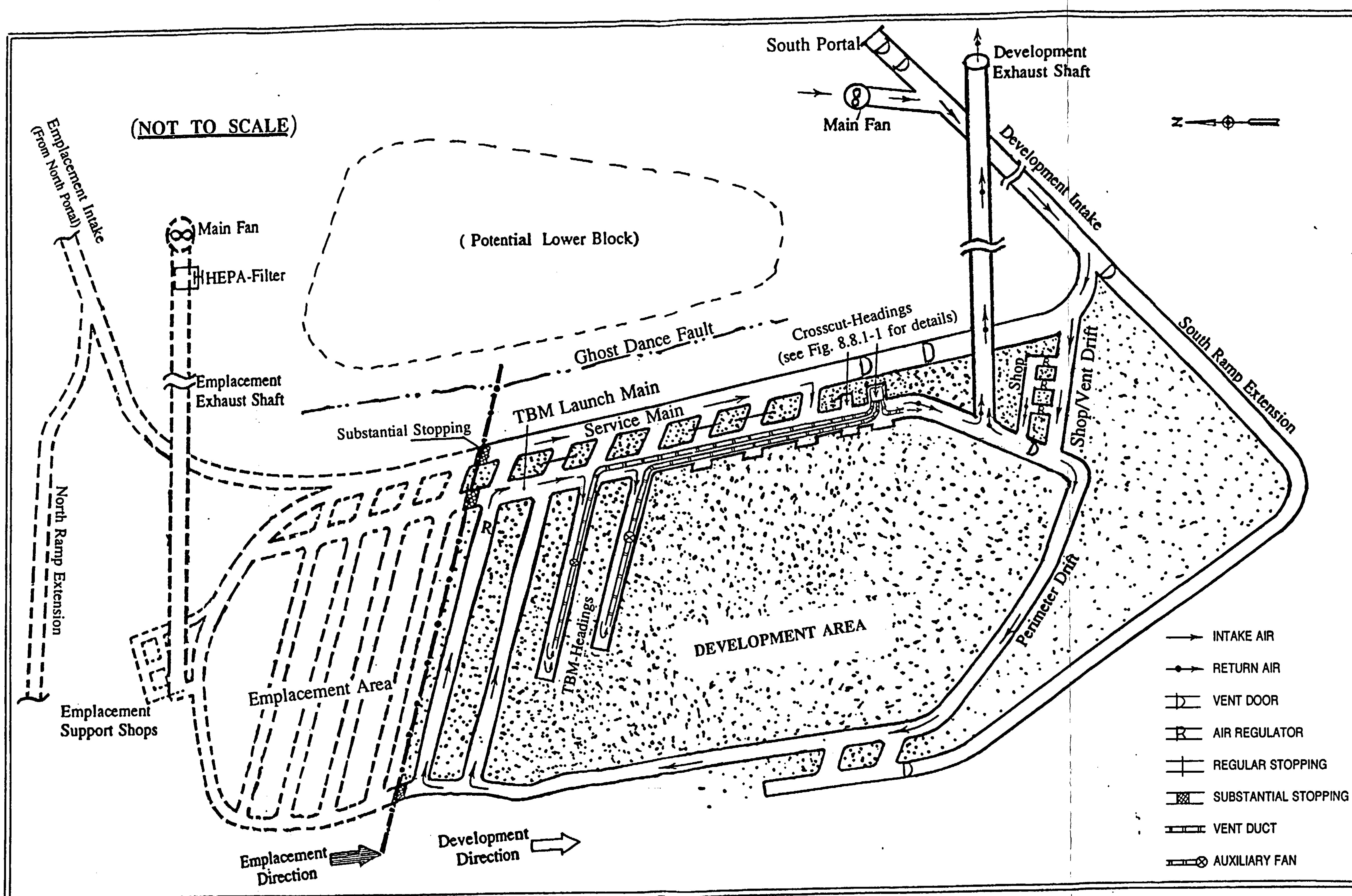


Figure 8.8-1
Ventilation Network Diagram
for Development Side of Layout

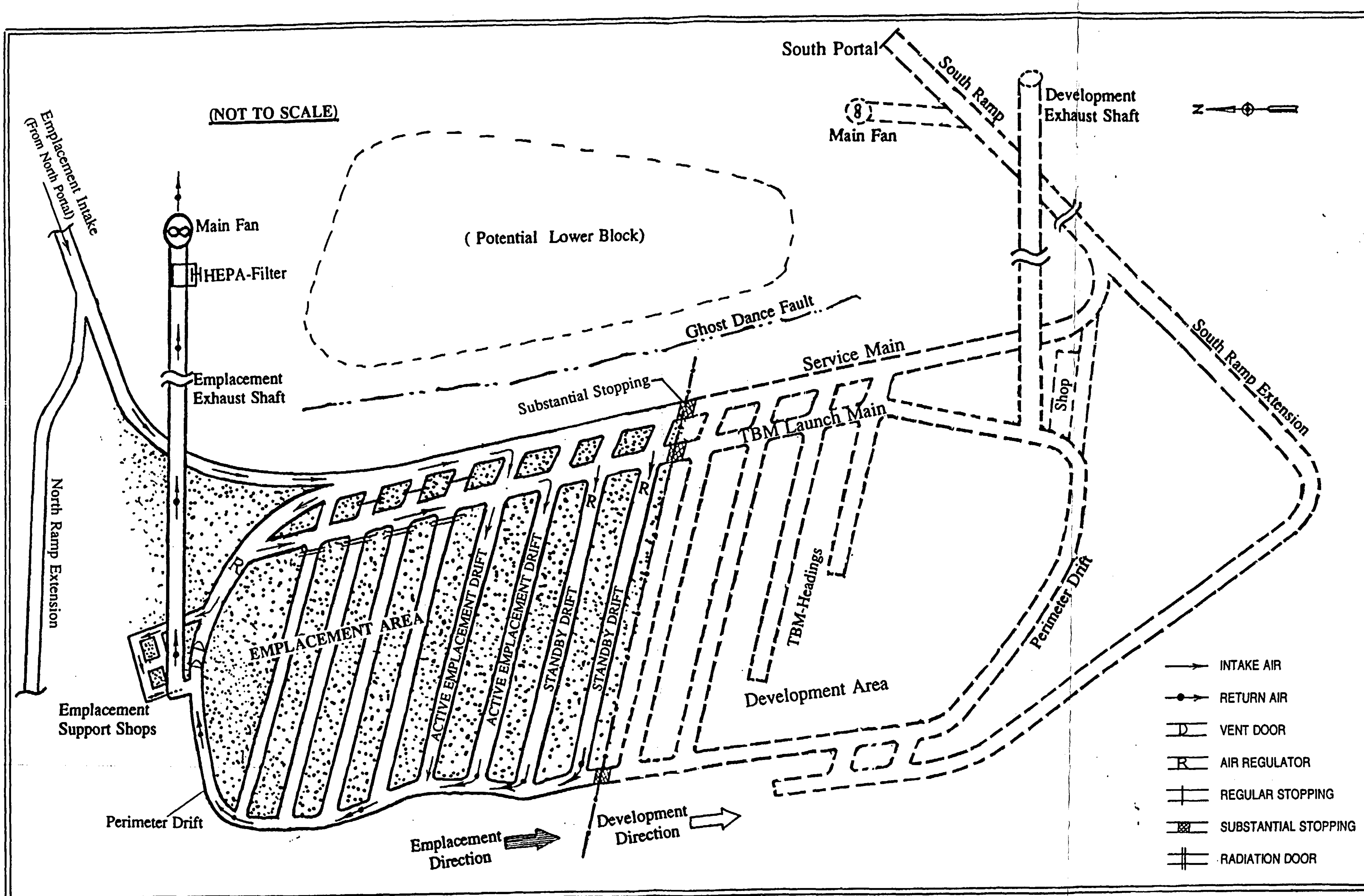


Figure 8.8-2
Ventilation Network Diagram for Emplacement Side of Layout

The ventilation network diagram for the development side (Figure 8.8-1) illustrates the concepts of the development ventilation system and air flow arrangements. In addition to the two main ramps constructed during site characterization, two vertical shafts would be constructed, one north and one south, in order to establish the two independent ventilation systems necessary for simultaneous development and emplacement operations. The bottoms of these shafts would be connected to the perimeter main at the north and south ends of the repository. After completion of construction for the shafts and main drifts, development of the emplacement drifts would begin, advancing from north to south, followed by emplacement.

The intake air for development side operations would be brought through the South Ramp, followed by a short ventilation supply drift, the west side perimeter main, and into two or more excavated emplacement drifts (awaiting turnover to emplacement operations) that deliver the fresh air to the launch and service main drifts. Fresh air for active emplacement drift headings being excavated by the TBMs is drawn into the ends of these drifts from the service and/or launch mains by auxiliary fans and ventilation duct that extend to the TBM cutterhead and that operate in an exhausting, or locally negative pressure mode. Dusty air from the TBM cutting zone is routed through the TBM dust scrubbers and directly into the ventilation duct that extends beyond the crosscut headings located in downstream airflow, thereby allowing personnel in both developing emplacement drifts and crosscut areas to always work in fresh intake air. Return air in the launch main exits via the south perimeter drift section, and is exhausted to the surface through an exhaust shaft. As shown in Figure 8.8.1-1, crosscut development headings would also be ventilated using auxiliary fans and duct that operate in a suction mode. The air supply for developing crosscuts is supplied from the upstream launch main where the flow contains no potential dusty air exhausted from the TBM operations; the return air from the crosscut faces would exhaust through portable dust scrubbers into the launch main, then into the perimeter main which is connected to the exhaust shaft.

Figure 8.8.1-1 also illustrates that the used air from the TBM headings (scrubbed by a built-in dust collector) is directed into ventilation ducts, then through a portable dust scrubber for further dust reduction, before discharging into the main return air stream. At the muck car dump and conveyor feeder station, potential dusty air produced during dumping and conveyor loading operations can be drawn through an exhaust hood installed over the conveyor transfer point (Figure 8.7.1-7). Dust would be collected through a portable scrubber before the used air enters the launch main. A relatively small quantity of air would be split from main intake air in the ventilation drift near the shop area to ventilate potential development support shops that might be needed in the subsurface; the used air from the shops would be directed into the nearby perimeter main and then the exhaust shaft.

The required airflow quantities for underground development areas are estimated and summarized in Table 8.8.1-1. The air flow rates are generally determined by the need to supply fresh air for personnel and special TBM operations, and to control air temperature, dust and potential emission from diesel equipment in the repository.

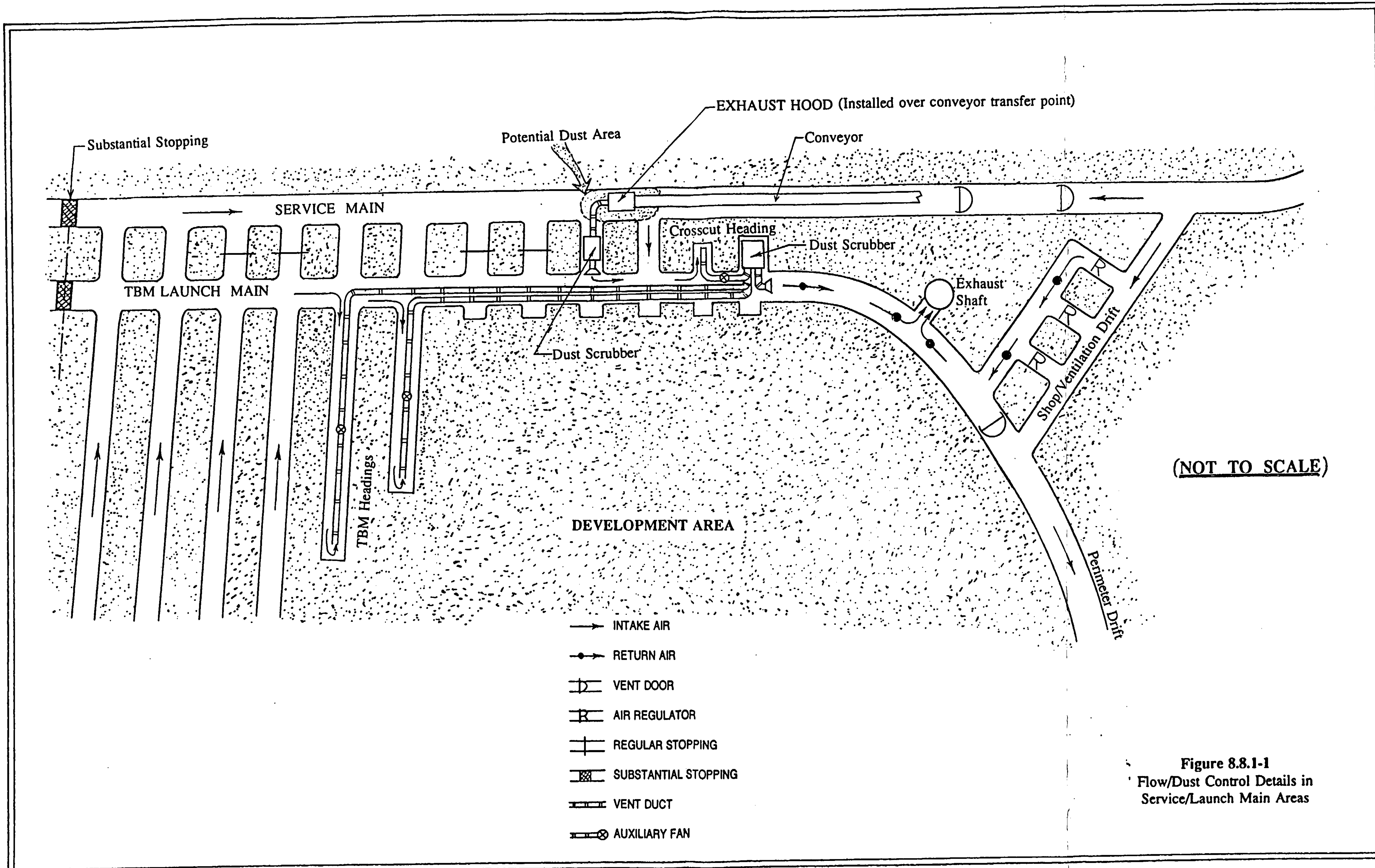


Figure 8.8.1-1
Flow/Dust Control Details in Service/Launch Main Areas

Table 8.8.1-1. Estimated Air Quantity for Development Operations

Development Area	Required Air Quantity (m^3/s)	Design Air Quantity* (m^3/s)
Emplacement Drift (TBM Heading #1)	27.12	33.90
Emplacement Drift (TBM Heading #2)	27.12	33.90
Emplacement Drift (Postexcavation Construction, 8 Drifts)	48.72	60.90
Crosscut (Roadheader)	24.88	31.10
Crosscut (Drill and Blast)	20.24	25.30
Shop Maintenance	25.96	32.45
	Total	217.55

* Includes 20 percent of total for leakage/uncertainty allowance.

Figure 8.8.1-2 illustrates the general ventilation air flow quantity distribution on the development side. The results are obtained from the Subsurface Ventilation Concepts Report for Repository ACD-FY 1994 (M&O 1994q), which was prepared using the interim layout concept described in Section 8.6.4.

For the typical ranges of air quantity requirements and the general concepts of air flow distribution presented herein for the interim layout concept, the ventilation equipment and devices are expected to be similar to those used in conventional underground mining facilities, including main and auxiliary fans, bulkheads (or stoppings), air regulators, air doors, air locks, ventilation duct or tubing, air quality monitoring devices and dust collectors. More in-depth evaluation of these facilities will be addressed in future repository ACD ventilation studies.

8.8.2 Emplacement System Quantities and Distribution Concepts

Figure 8.8-2 is a conceptual illustration of the ventilation system for the emplacement area. Ventilation intake air for the emplacement side of operations is supplied via the north (waste) ramp, then directed to the active emplacement drifts and standby drifts through either the service main, or through the emplacement operations end of the TBM launch main. Return air is directed into the west side perimeter drift, and then exhausted through the emplacement exhaust shaft. If an accident were to result in the release of radionuclides, the return air would be routed through a bank of HEPA filters before being discharged to the atmosphere.

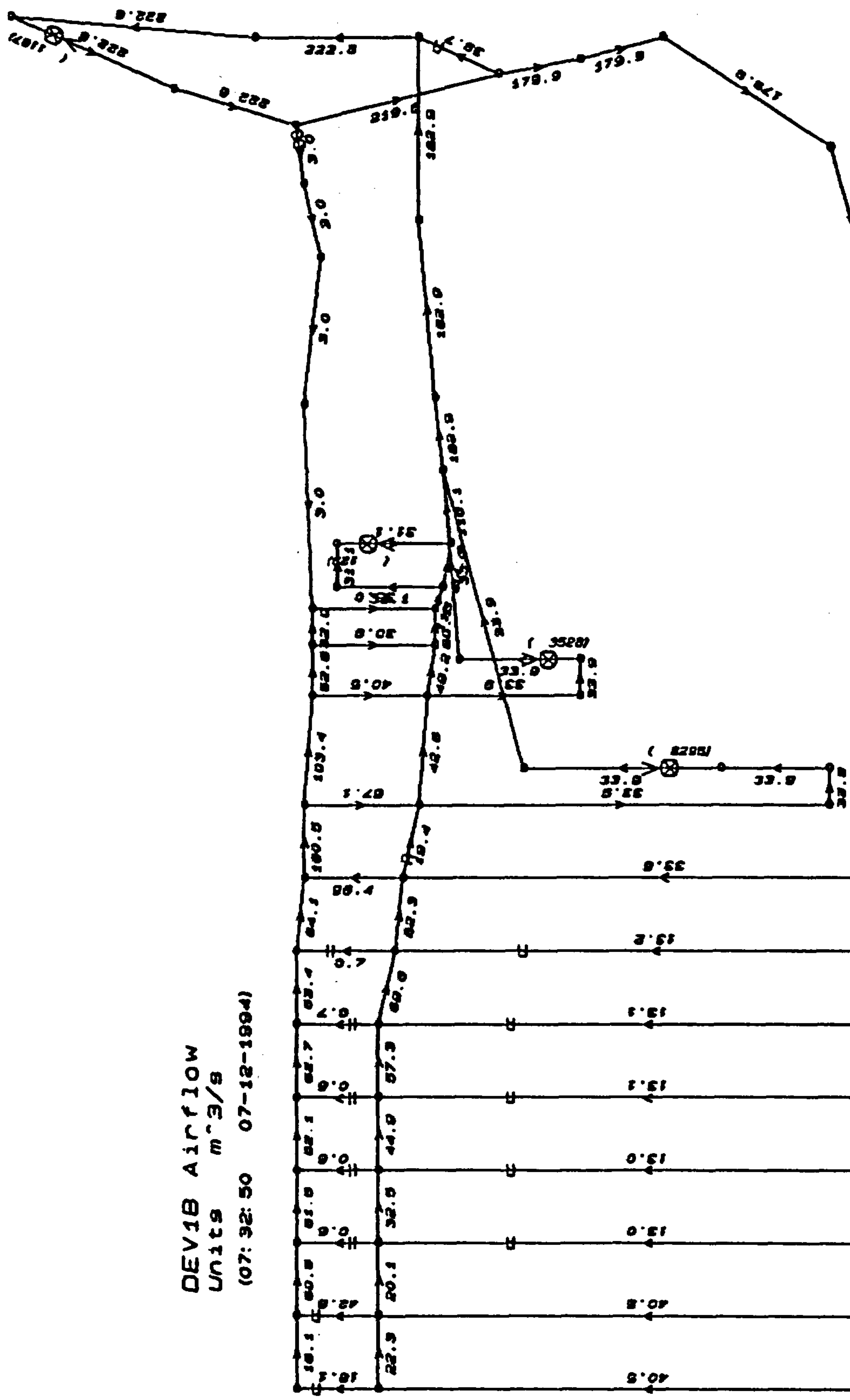


Figure 8.8.1-2. General Air Flow Quantity Distribution on Development Side of Layout

During emplacement of WPs, heat released from waste will increase temperatures of air flowing in the emplacement drifts and the surrounding rock. The impact of heat load on the ventilation air flow must be evaluated, in addition to the considerations of ventilation for general underground operations. Based on an assumption in the CDA, the design air flow must be capable of maintaining an acceptable air temperature less than 50°C in the operating drifts (M&O 1994m, DCSS-019).

The required airflow quantities for underground development areas are estimated and summarized in Table 8.8.2-1. The results are obtained from the Subsurface Ventilation Concepts Report for Repository ACD-FY 1994 (M&O, 1994q), which was prepared using the interim layout concept described in Section 8.6.4. The air flow rates are generally determined through analysis of the conduction, convection and radiation heat transfer processes in the drift during waste emplacement operations, and the need to supply fresh air for general emplacement related activities in the repository. Figure 8.8.2-1 illustrates the general ventilation air flow quantity distribution on the emplacement side. These typical ranges of air quantity requirements and the general arrangement of air flow distribution indicate that the temperature of the operating emplacement drifts can be controlled within an acceptable level with adequate air flow in the same order of magnitude as that for development drifts; thus, commonly accepted underground ventilation principles may be used in design of ventilation for the repository emplacement operations.

Table 8.8.2-1. Estimated Air Quantity for Emplacement Operations

Emplacement Area	Required Air Quantity (m^3/s)	Design Air Quantity* (m^3/s)
Emplacement Drift #1	30.81	38.51
Emplacement Drift #2	30.81	38.51
Supporting Shops	25.96	32.45
Standby Drift #1	6.09	7.61
Standby Drift #2	6.09	7.61
	Total	124.69

* Includes 20 percent of total for leakage/uncertainty allowance

8.8.3 Emergency and Escape Considerations

Each emergency situation is unique. Systematic analysis of accident scenarios is an extremely complex subject and generally involves a number of research topics including: development of accident scenario, event tree frequency and dose consequence analyses, and planning for emergency responses. Comprehensive study and modeling of the accident scenarios require efforts beyond the scope and effort for this stage of the design study.

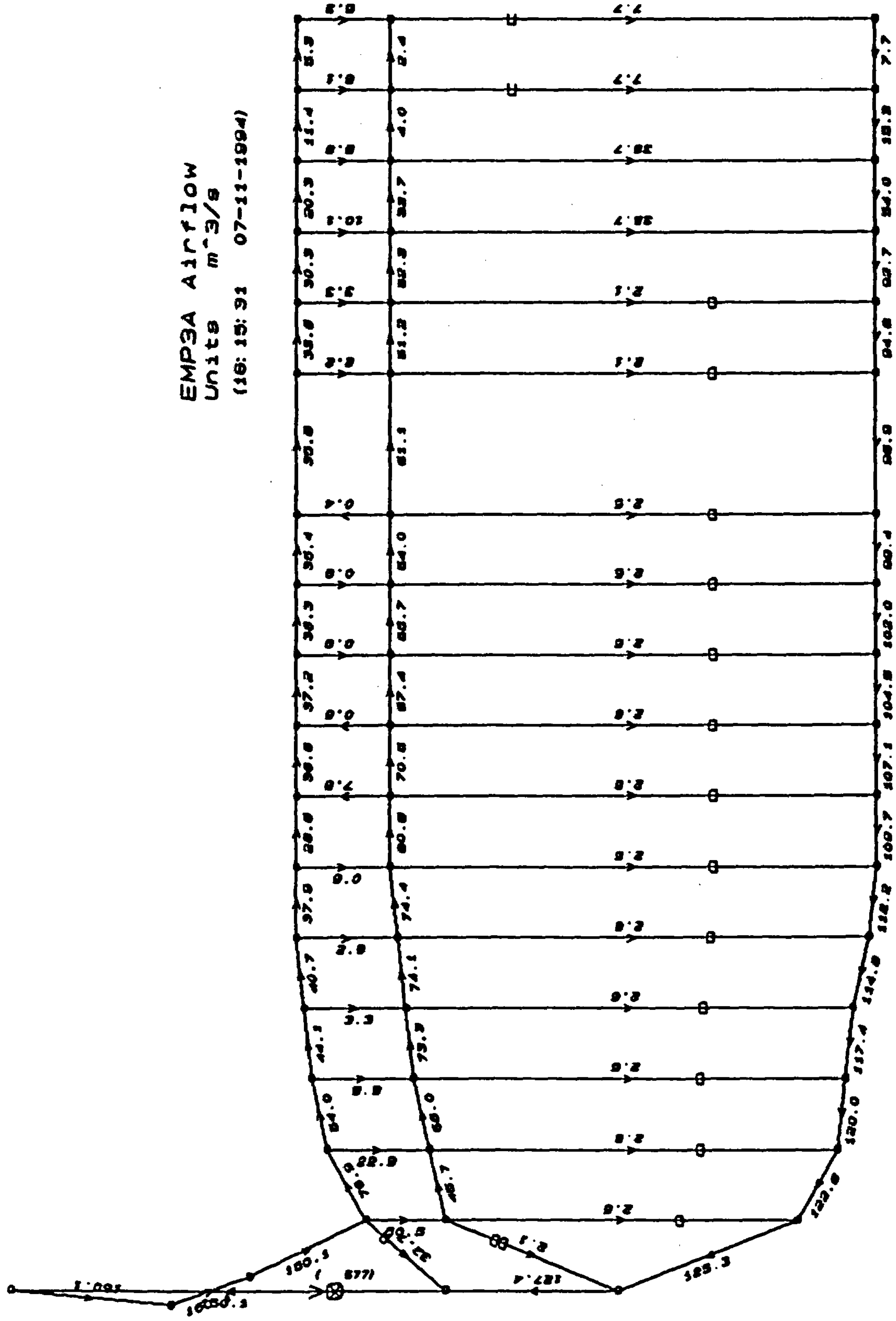


Figure 8.8.2-1. General Air Flow Quantity Distribution on Emplacement Side of Layout

This section is intended to provide a preliminary discussion of some generic considerations regarding potential escape routes for underground personnel during some accident scenarios. The following discussions are based on the underground ventilation schemes presented in the previous two sections.

Potential contaminants, either accidently released radioactive materials in the form of gas or suspended particulates, or products of combustion generated by accidental underground fires, will follow the prevailing winds and be carried to the downstream areas from the original source location. Although fires can themselves alter ventilation air flow conditions, during the initial stage of a fire, and while the underground areas are being evacuated, the air will generally continue to flow in the original direction. Consequently, potential escape routes can be planned according to the air flow schemes and potential locations of contamination sources. Some examples of the preliminary considerations that may allow personnel in underground areas to travel in uncontaminated air streams and to reach the surface areas are presented as follows. It is worth noting that the following examples are used generically for the purpose of illustrating that underground personnel can escape from anywhere in the underground facility regardless of the accident location. The actual schedules for emergency responses will depend on detailed accident analysis.

Fire in developing emplacement drift:

- Personnel in TBM headings: ⇒ excavated crosscuts ⇒ service main ⇒ South Ramp ⇒ surface. Alternatively, from the TBM headings ⇒ launch main ⇒ excavated emplacement drift ⇒ perimeter main ⇒ shop/vent drift ⇒ South Ramp ⇒ surface.

- Personnel in crosscut headings: ⇒ launch main ⇒ existing crosscut ⇒ service main ⇒ South Ramp ⇒ surface.

- Personnel in excavated emplacement drifts: ⇒ existing crosscut ⇒ service main ⇒ South Ramp ⇒ surface. Alternatively, ⇒ perimeter main (west side) ⇒ shop/vent drift ⇒ South Ramp ⇒ surface.

- Personnel in development shop area: ⇒ vent drift ⇒ South Ramp ⇒ surface.

Fire in South Ramp (main intake air stream):

- Personnel in TBM and crosscut headings: ⇒ launch main ⇒ stopping (at north end of development area in launch main) ⇒ buffer zone or refuge station in emplacement area (as discussed in Section 8.7.2.1).

- Personnel in excavated emplacement drifts: ⇒ launch main ⇒ stopping (at north end of development area in launch main) ⇒ buffer zone or refuge station in emplacement area.

  Alternatively, from excavated emplacement drifts ⇒ perimeter main ⇒ stopping (at north end of development side in perimeter main) ⇒ buffer zone or refuge station in emplacement area.

- Personnel in west section of perimeter main of development area or in development shop area: ⇒ perimeter main ⇒ stopping (at north end of development side in perimeter main) ⇒ buffer zone or refuge station in emplacement area.

Fire in developing crosscuts: (similar routes to those for fire in developing emplacement drift).

Fire in the development shop area: (similar routes to those for fire in developing emplacement drift except that the alternatives involving the use of the shop/vent drift will not be available).

Contaminant release in active emplacement drift or standby drift:

- Personnel in active emplacement drift or standby drift: ⇒ nearby crosscut ⇒ service main ⇒ North Ramp ⇒ surface.

- Personnel in emplacement shop area: ⇒ perimeter main ⇒ North Ramp ⇒ surface. Alternatively, from shop area ⇒ perimeter main ⇒ stopping (at south end of emplacement side in waste handling main) ⇒ buffer zone or refuge station in development side.

Contaminant release in North Ramp:

- Personnel in active emplacement drift or standby drift: ⇒ perimeter main (west side) ⇒ stopping (at south end of emplacement side in perimeter main) ⇒ buffer zone or refuge station in development side.

- Personnel in emplacement shop area: ⇒ emplacement exhaust shaft ⇒ surface. Or, from shop ⇒ perimeter main (west side) ⇒ stopping (at south end of emplacement side in perimeter main) ⇒ buffer zone or refuge station in development side.

Contaminant release in waste handling main:

- Personnel in active emplacement drift or standby drift: ⇒ perimeter main (west side) ⇒ stopping (at south end of emplacement side in perimeter main) ⇒ buffer zone or refuge station in development side. Alternatively, from emplacement drift ⇒ nearby crosscut ⇒ service main ⇒ North Ramp ⇒ surface.

- Personnel in emplacement shop area: ⇒ perimeter main ⇒ North Ramp ⇒ surface.

8.9 SUBSURFACE DRAINAGE

The interim layout is designed to drain any water seeping into the main drift openings toward a sump located at the emplacement exhaust shaft. Figure 8.9-1 provides approximate elevations at key points in and around the layout block. Figure 8.9-2 portrays the resulting general drainage pattern. As noted in Section 8.6.4.6, the emplacement drifts in the interim layout are flat-lying, and the design would be adjusted later to facilitate drainage out of these drifts if the concept undergoes further refinement. The emplacement drifts would then drain into one of the main drifts, and on toward the emplacement exhaust shaft as described above.

The bulkheads or air stoppings described in Section 8.8, which physically separate the development and emplacement sides of the repository, present a problem for drainage in that they block the flowpath in the main drifts. Water encountered on the development side of the repository would flow toward these stoppings. There it would be collected in a sump at each stopping location and either pumped through the stopping to the emplacement side, or to the surface through discharge pipelines hung in the service and perimeter mains. Any leakage through the stoppings would be from the development to the emplacement side, similar to ventilation air leakage at these locations.

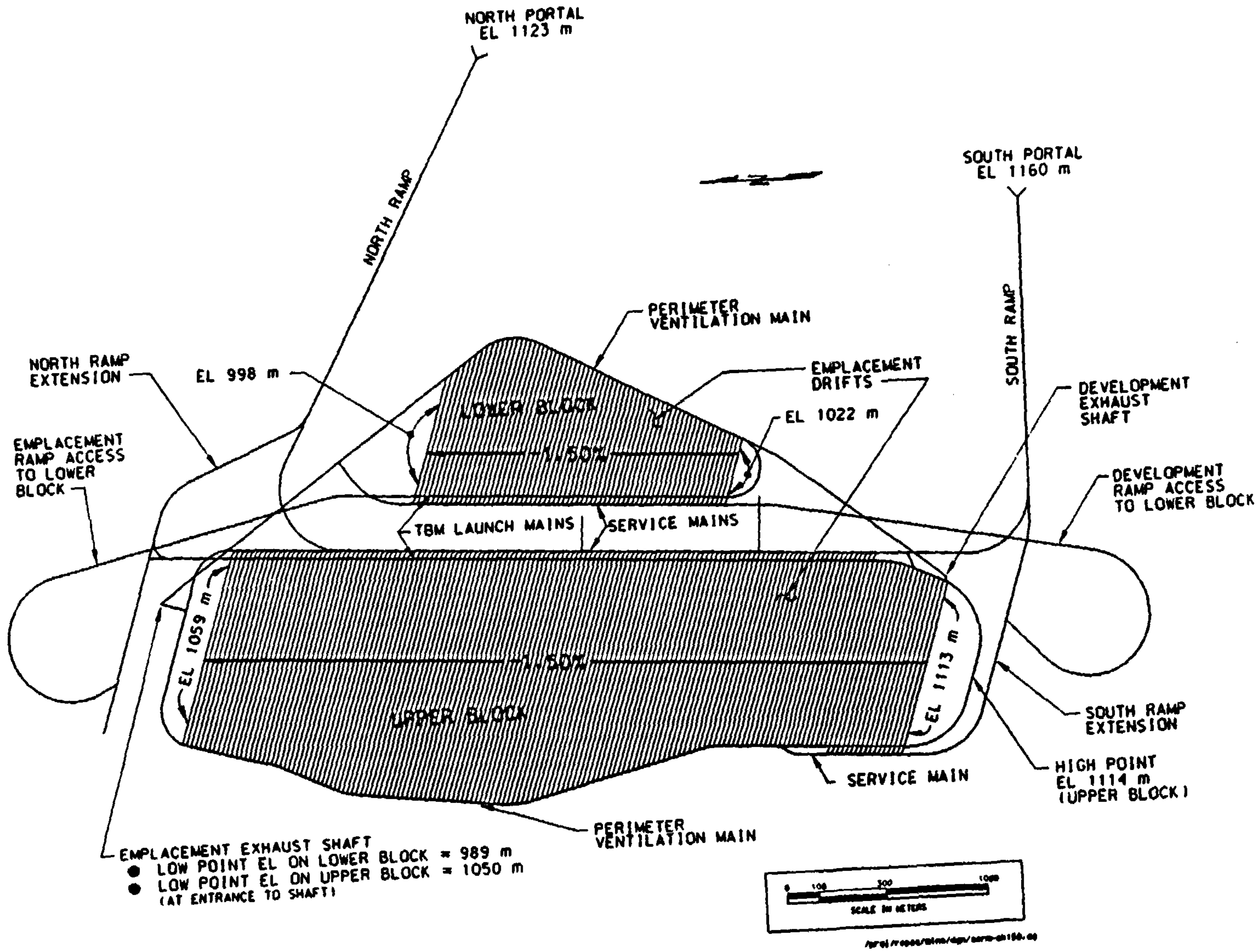


Figure 8.9-1. Elevation and Grade Data-Interim Layout

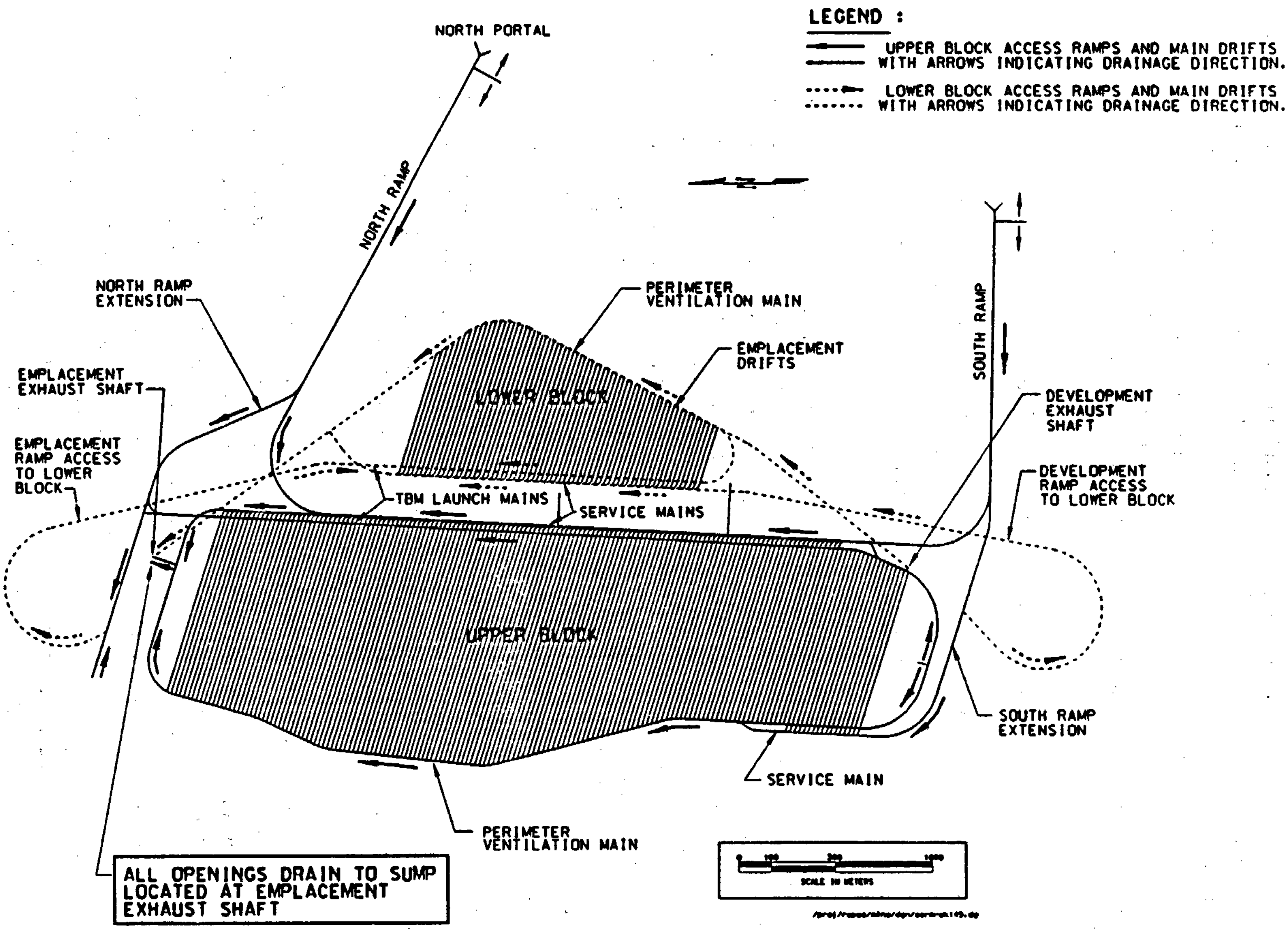


Figure 8.9-2. Subsurface Drainage Pattern-Interim Layout

8.10 SUBSURFACE SUPPORT SERVICES AND UTILITIES

As ACD progresses, new concepts for excavation and transport equipment, repository layout, and available access corridors to the subsurface will have a significant influence in the configuration and location of subsurface facilities and utilities. This section provides a preliminary assessment of several of the more significant changes that have taken place during repository ACD which will affect subsurface support facilities. The general utility corridors into the repository using the latest ACD repository layout concepts are also identified.

8.10.1 DEVELOPMENT SIDE SUPPORT FACILITIES

Development side support facilities will generally be comprised of the warehousing and maintenance facilities needed to support development side construction operations. Major issues to be addressed in this area include the extent of facilities that should be placed underground versus on the surface.

In the SCP-CD, the majority of equipment requiring regular maintenance consisted of diesel powered, rubber-tired mining equipment. In production mines, it is often most economical to perform the majority of maintenance work on large fleets of this type of equipment in underground shops, rather than incurring the delays and costs to transport such equipment to surface shops. This was the philosophy adopted in the SCP-CD repository design. Significant changes in subsurface excavation and equipment concepts have occurred as ACD progresses. TBMs will perform the majority of excavation work (M&O, 1994m, DCSS-005). Rubber-tired, diesel-powered equipment used in previous repository conceptual designs has been replaced by rail equipment to the extent practical (M&O, 1994m, Key 010, 030). Electricity as the prime mover of rail equipment by trolley and/or battery is now a potentially preferred option due to the unanswered question of the effects of diesel exhaust components on waste isolation. Access corridors to the subsurface which are available for equipment transportation during maintenance have also changed, as discussed in the next paragraph. A reevaluation of the types of maintenance activities required for current ACD equipment concepts, as well as the economics of the location of needed maintenance facilities–surface versus underground–is necessary.

In the interim design, use of the South Ramp as a rail transport corridor, as discussed in Section 8.7.1.3, will potentially allow much faster and more efficient transportation of supplies to the subsurface areas than in previous repository conceptual designs, such as the SCP-CD. The limited number of active working places and continuous nature of TBM advance, which requires a steady stream of supplies, must be considered as a factor in addressing the logistics of supplies transport and distribution. In the SCP-CD, supplies transport was accomplished through a personnel and materials shaft and by rubber-tired equipment, making underground warehousing facilities potentially more critical than current repository concepts. Excavation operations were also cyclical in nature, using drill-and-blast methods with many working places available. The assumptions on subsurface warehousing made in the SCP-CD may no longer be valid, and require reevaluation.

These aspects will be further addressed as ACD progresses.

8.10.2 Emplacement Side Support Facilities

An examination of the required emplacement side support facilities has not been performed at this stage of ACD. These aspects will be further addressed as ACD progresses.

8.10.3 Subsurface Utilities

This subsection provides a preliminary summary of the major types of subsurface utilities that will be required to support subsurface repository development and emplacement operations; although quantity and size estimates have not been performed to date. The major utility corridors to the repository block and within the block are also described.

The South Ramp will serve as the primary utility corridor for both the repository development and emplacement side subsurface utilities, in addition to its transport and muck handling route functions. Figure 8.6.4-4 (Section 8.6.4.7) shows the relative positions of permanently installed utilities in the ramp.

Permanent electrical utilities to be installed in the ramp include high voltage electrical cables serving as the primary subsurface feed, low voltage electrical cables for power to trolley, ramp lighting, conveyor booster drives, ramp utility outlets, and communications and monitoring cables. Piping to be installed in the ramp includes a primary subsurface dewatering line, a compressed air line, and separate pipes for fire water, chilled water, potable water, and service water.

The development exhaust shaft will also carry some utilities to the repository block; however, the shaft will function as a corridor only for those utilities necessary as a repository backup source, those necessary to operate the shaft, and for those best located in an exhaust airway. Figure 8.6.4-6 (Section 8.6.4.9) shows the general cross section of the shaft with the planned permanently installed utilities which include a high voltage electrical cable serving as a subsurface redundant or loop feeder, low voltage electrical cable for shaft and shaft station power, and communications and monitoring cables.

Utilities in the North Ramp will be minimized because it will serve as the waste transportation route. The ramp will carry only low voltage electrical power cable(s) for ramp lighting and trolley power, and monitoring and signaling cables, as shown in Figure 8.6.4-1 (Section 8.6.4.1).

Utilities in the emplacement side exhaust shaft will also be minimized. Since the shaft functions as an exhaust airway for the emplacement side, it will be a potential radiation hazard area under certain accident or abnormal scenarios involving radionuclide release in the emplacement area. Activities in the shaft will therefore be kept to a minimum involving only periodic shaft inspection. Permanent utilities installed in the shaft will include only a cable to allow communications between the surface and the shaft station.

The service main will carry the above described utilities once on the repository block, and preliminary locations for them are included on the service main cross section in Figure 8.7.1-7 (Section 8.7.1.2).

Piping utilities that would be required to support development operations include the dewatering, compressed air, service water, and as an option, the potable water lines. To support emplacement side operations and maintenance functions, installed piping could potentially include subsurface dewatering, compressed air, fire water, service water, potable water, and chilled water. Chilled water may be necessary to support local cooling operations not reasonably provided by the repository ventilation system for specific operating or maintenance functions.

Separate electrical utilities would be required to support development operations and emplacement operations. Power supply and instrumentation cables needed only for development operations would be removed prior to turnover of the construction area to the emplacement side.

8.11 LOWER THERMAL LIMITS AND EXPANSION CONSIDERATIONS

The Mission Plan (DOE, 1985) targets the first nuclear waste repository for a storage capacity of 70,000 MTU. This goal is carried forward in the CDA (M&O, 1994m, Key 003, 005). The total subsurface area required for emplacement of waste depends, to a large extent, on the thermal loading that is determined to be desirable. Other factors that could increase the total areal requirement include the possible presence of undetected, non-suitable geologic conditions in some locations. Definition of a thermal loading appropriate for Yucca Mountain is the subject of numerous, ongoing studies at this time. For purposes of this report and consistent with the CDA (M&O, 1994m, Key 019), two scenarios are considered:

A. A high thermal loading scenario that will produce "above-boiling" conditions in the repository; taken to be in the range of 80 to 100 MTU/acre, which is equivalent to 91 to 114 kW/acre based on average 22.5 year old, 42.2 GWd/MTU burnup fuel at the time of emplacement (M&O, 1994m, Key 004).

B. A low thermal loading scenario that will produce mostly "below-boiling" conditions (except for areas within a few meters of the WPs) in the repository; taken to be in the range of 25 to 35 MTU/acre, or 28 to 40 kW/acre at the time of emplacement for average fuel.

Figure 8.11-1 presents the net area available for emplacement of waste in the interim layout. Ignoring the possibility that geologic conditions might preclude waste emplacement in certain zones, the darkened portions of the layout represent the area over which the waste could be emplaced on a regular pattern. Based on the darkened areas shown on the figure, and assuming geologic conditions are favorable throughout the entire area, the layout could accommodate the total, 70,000 MTU waste inventory at a mass loading of approximately 82 MTU/acre or higher using just the upper block. Using both the upper and lower blocks, a mass loading of approximately 66 MTU/acre or higher could be accommodated for the full, 70,000 MTU inventory. Alternatively, because 66 MTU/acre does not fit either of the thermal loading cases considered in the CDA, a repository containing both the upper and lower blocks could accommodate the 70,000 MTU waste inventory at a mass loading of 80 MTU per acre with an approximate 20 percent contingency area available for unforeseen geologic conditions that are deemed unsuitable for waste disposal.

The unshaded portion of the layout between the main drifts and the shading is a 35 meter wide thermal barrier, or standoff zone. Requirements for this feature were discussed in Section 8.3.3; it acts to prevent heat buildup in the main access drifts.

The interim layout uses essentially all portions of the primary area that could be logically developed using the operational schemes described in earlier sections of the report. As mentioned in Section 8.3.2, the primary area cannot accommodate the full, 70,000 MTU inventory if the lower, 25- to 35-MTU/acre thermal loading case were adopted. Based on the darkened areas shown on Figure 8.11-1, only 26,400 MTU could be emplaced at a mass loading of 25 MTU/acre, or 37,000 MTU at a mass loading of 35 MTU/acre.

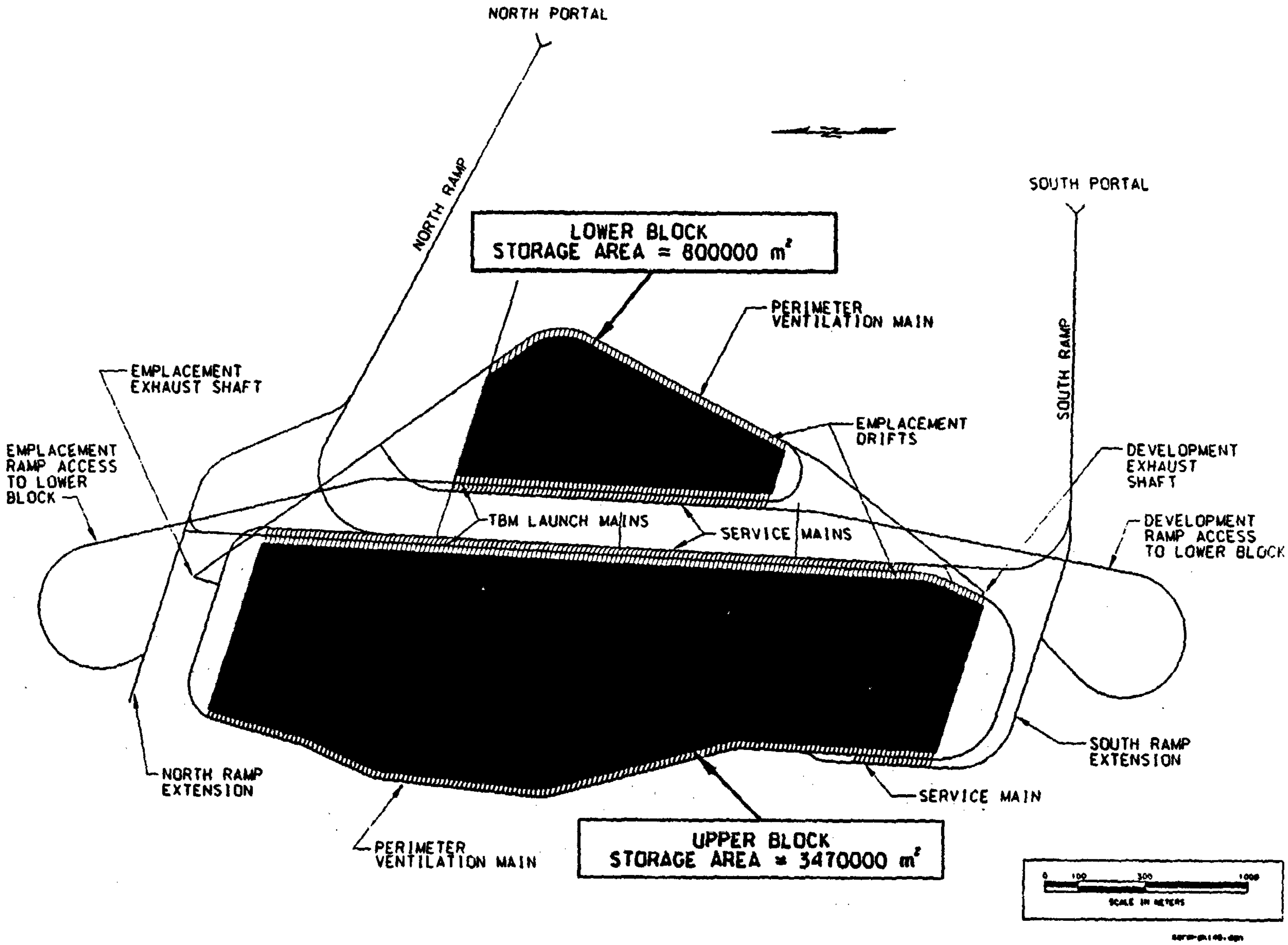


Figure 8.11-1. Net Area Available for Emplacement-Interim Layout

Expansion outside of Area 1 has been given brief consideration in early repository work (SNL, 1984c) as well as in the SCP (DOE, 1988, pp. 8-14 to 8-17). Six potentially useable areas have been previously identified (refer to Figure 8.3.2-3 in Section 8.3.2). It should be noted that the numbering of the potentially useable areas does not reflect any significance in their ranking (SNL, 1984c, p. 10).

In the issues hierarchy of the SCP, Design Activity 1.11.3.2 - "Useable Area and Flexibility Evaluation" (DOE, 1988, p. 8.3.2.2-48) specifies parameters necessary to satisfy SCP Information Need 1.11.3. Information Need 1.11.3 consists of design concepts for orientation, geometry, layout, and depth of the underground facility that contribute to waste containment and isolation including flexibility to accommodate site-specific conditions. Work relative to this issue has been performed in support of thermal loading system studies, and is incorporated in a 1994 M&O report (M&O, 1994c). In this report, design objectives similar to the interim layout were applied to develop preliminary layouts outside of Area 1 but within the TSw2 rock unit. The layouts contained in that 1994 report partially fulfill Design Activity 1.11.3.2 within limitations of currently available geologic data outside of Area 1. The layouts also demonstrate the feasibility of expansion, using current design concepts, should contingency areas need to be developed to accommodate site specific conditions.

A current assumption in the CDA is that the repository horizon will be located within the TSw2 rock unit in the primary area (M&O, 1994m, Key 022). This project assumption currently precludes more comprehensive subsurface design activities outside of the primary area, which makes up the majority of Area 1.

8.12 RETRIEVAL CONSIDERATIONS

The Nuclear Waste Policy Act (NWPA) as amended, states that any repository shall be designed and constructed to permit retrieval of any spent nuclear fuel placed in the geologic repository, during an appropriate period of operation of the facility, for any reason pertaining to the public health and safety, or the environment, or for any purpose of recovery of the economically valuable contents of the spent fuel.

Under current assumptions in the CDA (M&O, 1994m, Key 017), retrieval of emplaced waste will be performed for only the following reasons:

- Failure in the site or WP or some other system, causing a possible risk to public health.
- DOE would have determined that recovery of valuable resources from the spent fuel is necessary.

In addition, a fundamental program requirement listed in 10 CFR 60.111(b) is that the repository design shall include provisions for retrieving the waste from its emplacement location throughout the operational and caretaker periods. Under current statutes, the period required for retrievability is 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by the NRC. In keeping with the last statement, the desirability or viability of extended retrieval periods is being given consideration in the OCRWM program, and a key assumption in the CDA upon which repository conceptual design is being based is that the repository will be designed for a retrievability period of up to 100 years after initiation of emplacement (M&O, 1994m, Key 016).

Performance confirmation activities during the caretaker period may require a small number of WPs (compared to the total emplaced inventory) to be removed. Performance confirmation will provide the NRC with the basis for a decision to allow closure and decommissioning of the MGDS. To confirm performance of the WPs emplaced in the disposal environment, tests may be performed by instrumentation and sampling.

Removal of emplaced WPs from their disposal location for purposes of performance confirmation is not considered to be retrieval under the regulatory definitions of retrieval as applied to the Yucca Mountain MGDS. The planned performance confirmation activities and their influence on repository design are not well defined at the current stage of ACD. In order to aid in performance confirmation, an option in future repository designs may be to include specific performance test areas where WPs can be emplaced or examined as part of the confirmation processes if these areas are determined to provide representative data.

While retrievability is a requirement for MGDS design and licensing, the degree to which retrieval should influence the design of the subsurface openings in the repository is largely a function of how easy a task retrieval should be. A second aspect of retrieval is the ability or desirability to maintain openings in a state of readiness for retrieval while waste is emplaced in them.

An illustration of the retrieval issues that must be considered in the design of the repository, and particularly in the selection of an emplacement concept, can be made. For example, emplacement drifts can be designed to be large enough to allow WPs to be accessed individually, without disturbing other packages. Such is the case in the Off-Center-In-Drift emplacement concept described in Section 8.5.1.1, where selective retrieval capability is provided. That capability, however, does not enhance the basic retrieval requirement. It only addresses the question of retrieval of WPs for performance confirmation or recovery of spent nuclear fuel as a resource. Also, with such a concept, clearance around the WPs may allow the option to conduct minor maintenance and repair functions in the drift if such an option is determined to be feasible from a personnel radiological safety viewpoint.

On the other hand, much smaller emplacement openings that require the sequential removal of all of the packages in the drift can also be considered, such as the ISDOR concept described in Section 8.5.1.1. With the small-drift concept, the basic retrieval requirement is also met; although, selective retrieval capability for performance confirmation or recovery of spent nuclear fuel as a resource can be achieved only by removing the WPs ahead of the required package. With a small-drift concept, clearance around the WPs would not allow the option to conduct maintenance and repair functions in the drift while WPs are emplaced.

The use of small diameter emplacement drifts in the interim layout subscribes to a philosophy that, while it maintains the full requirement to retrieve in a straightforward manner, it does not lend itself to make the task to remove a WP(s) for performance confirmation (if necessary) any easier than absolutely necessary. The rationale for this approach is that designing the repository toward optimized retrieval or WP removal functions, particularly when such retrieval/removal would only constitute a small number of the total inventory, is not appropriate.

Small drift emplacement also subscribes to the philosophy that the maintenance or repair of emplacement drifts (as determined in the future to be necessary) is better accomplished by temporarily moving the WPs out of them. The rationale for this is the complexity required to conduct maintenance and repair operations by remote means, and the reliability that would be needed for such an operation. Removing WPs from a drift before conditions deteriorate to a point where the operation no longer becomes practical allows maintenance and repair functions to be conducted with the care, reliability, and probability for success warranted for such an operation.

Such a philosophy also points to the desirability of identifying cost effective, robust support systems, to minimize the probability of the need for a major opening or ground support repair over reasonably long time frames such as a 100 year period of retrievability (M&O, 1994m, Key 016).

A general operational approach to subsurface retrieval is presented in the flowchart of Figure 8.12-1 and summarized in the following two subsections. The retrieval process begins with the following two steps shown in that figure.

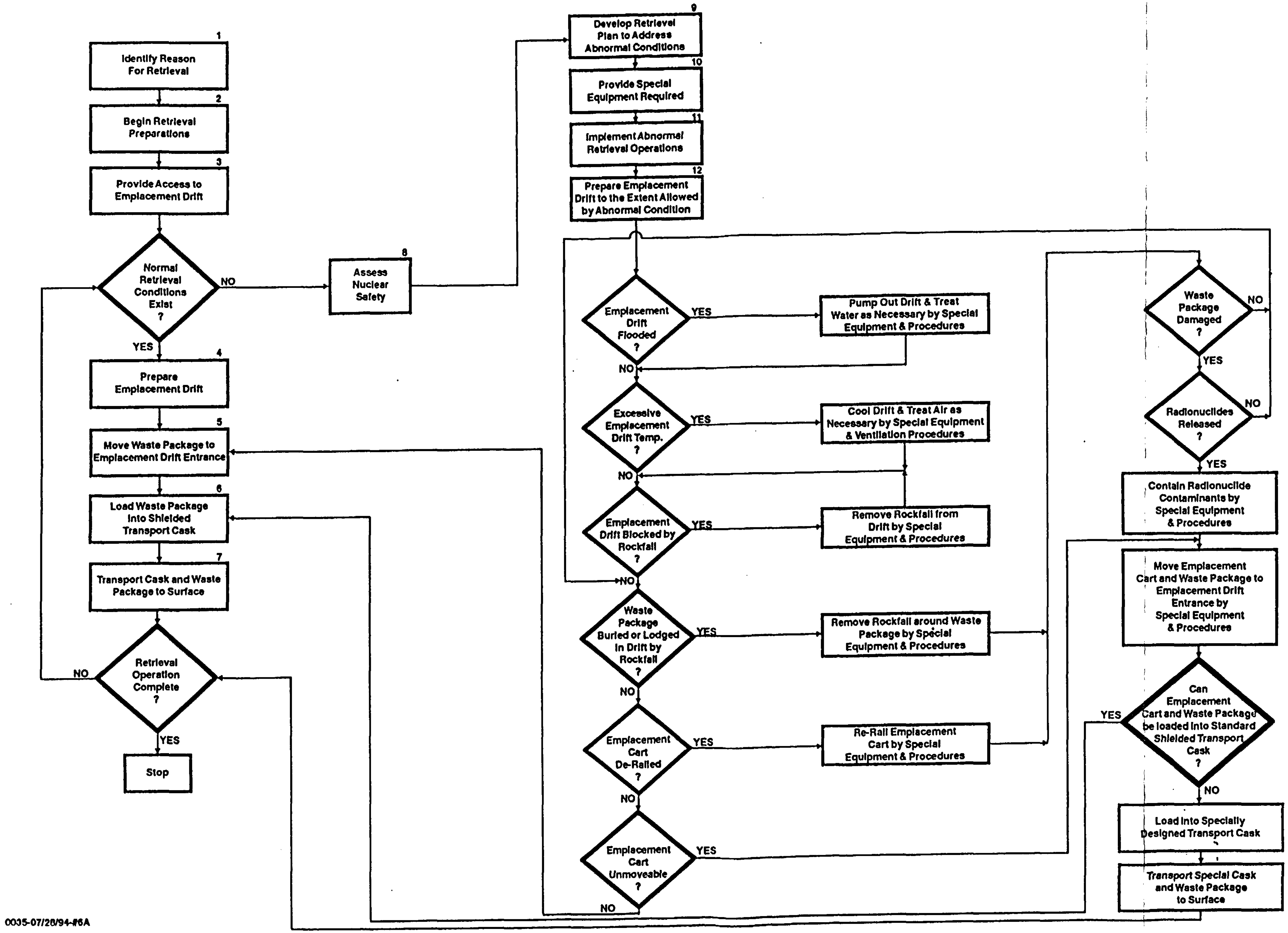


Figure 8.12-1
Preliminary Retrieval Operations Flow Chart

8.12.1 Pre-Retrieval Considerations

- Step 1- Identify Reason for Retrieval

  This step determines which of the two basic reasons that retrieval is necessary: (1) failure in the site, or the WP is causing a possible risk to public health, or (2) it has been determined by the DOE that recovery of valuable resources is necessary from some or all of the emplaced waste. The decision to retrieve represents an extraordinary event involving much effort with the possibility for incurring great cost.

- Step 2 - Begin Retrieval Preparations

  In the event that a decision to retrieve all or part of the emplaced waste is made, preparations for retrieval operations begin. Because of a 100-year period of retrievability (M&O, 1994m, Key 016), and because of the long time frames required, both for emplacement and retrieval, new retrieval equipment may be needed (see Section 8.12.4) and will be procured during this period. During retrieval operations, retrieval equipment may also require periodic replacement. Surface and subsurface support facilities will be brought to full operational capability. Facility modifications and additions (if any), incorporated into the original design of the repository but not constructed at that time, will be constructed to support the retrieval operations.

- Step 3 - Provide Access to Emplacement Drifts

  The first step in the sequence of subsurface retrieval operations will be to provide access to the emplacement drifts for the purposes of making an assessment of the conditions that will be encountered during retrieval. Retrieval conditions must be characterized because they may include, but may not be limited to, rock temperatures in the drifts, condition of the openings, radiation environment, and air quality. Because of the 100-year period of retrievability, and depending upon what time during that period retrieval is required, subsurface access drift and facility maintenance may be needed, which could include installation of supplemental ground support, and repair or replacement of portions of utilities and ventilation system components. However, to accommodate access for performance confirmation monitoring during the caretaker period, routine maintenance would be performed in major openings (access and primary ventilation drifts) during the period of retrievability, making such repairs at the time of retrieval relatively minor.

  As shown in Figure 8.12-1, a basic assessment of retrieval operations areas would define whether abnormal conditions exist and would identify portions of the emplacement drifts that would allow normal retrieval methods and those that exhibit abnormal conditions.

  An "abnormal" condition is defined as when the retrieval process must be performed with non-standard equipment or procedures. The existence of an abnormal condition may not necessarily mean that retrieval is impossible or particularly hazardous; in general, it means that modified equipment or procedures may be used. As defined by the SCP-CDR (SNL, 1987a), for a single-purpose canister type WP: "abnormal conditions may be precipitated by one or a combination of events such as tectonics, variability in rock characteristics, human error, aging and corrosion of equipment and facilities, and radiolysis."

It should be noted that current assumptions in the CDA for an MPC-based WP state that WP containment barriers will provide sufficient shielding for protection of materials from radiation-enhanced corrosion (M&O, 1994m, Key 031).

8.12.2 Normal Retrieval Operations

For those areas where normal conditions are assessed, normal retrieval can be summarized, using the interim layout and the in-small-drift-on-rail (ISDOR) emplacement concept for purposes of example, according to the following operational steps which are shown in the flowchart of Figure 8.12-1:

- Step 4 - Prepare Emplacement Drift

  One of the major aspects of emplacement drift preparation for retrieval is drift cooling. Ventilation is perhaps the most effective method to provide acceptable climate conditions for support of the retrieval activities in the emplacement drifts. Forced-air cooling of the previously unventilated emplacement drift with large quantities of ambient air will be used just prior to the time that reentry is necessary (Section 8.12.5). With the interim layout, the normal base of operations for retrieval is in the waste handling main drift and all actual WP personnel interfaces are conducted from this remote location. Since this main will function as the primary ventilation intake airway, temperatures there should remain cool throughout all phases of repository retrieval operations. Other preparation aspects could include repair or replacement of permanently installed fixtures in the drift needed for the retrieval operation that have deteriorated beyond a usable condition. Such fixtures could include rail and retrieval equipment control and power conductors; however, a detailed study of such deterioration has not been performed to-date during ACD.

- Step 5 - Retrieve WP from Emplacement Drift

  During this step, the WPs and emplacement carts are moved by remote handling methods, one at a time and in the reverse order of emplacement, to the emplacement drift entrance.

- Step 6 - Load WP into Shielded Transport Cask

  Once a WP has been moved to the entrance of the emplacement drift, the emplacement drift shielding door is opened and the WP is loaded into a shielded transport cask in the waste handling main.

- Step 7 - Transport Cask and WP to Waste Handling Building Vault

  The final retrieval step for normal (and abnormal) retrieval operations is transportation of the shielded cask and package from the underground, via the North Ramp, to the surface waste handling vault. As shown in Figure 8.12-1, in the case of abnormal operations, the condition of the WP (damaged or intact) as well as the type of shielded transport cask required (if the WP or carrier has been significantly damaged), may represent a special condition requiring special equipment and procedures.

After completion of the above steps for normal retrieval of a WP, an opportunity is available to reassess the conditions within an emplacement drift under active retrieval. This is because retrieval of part of the WPs from any one emplacement drift may be possible under normal conditions while an abnormal condition may be present which might affect retrieval for one or more of the remaining WPs in the drift.

If normal conditions are still deemed to exist, then retrieval can proceed under the normal conditions described under steps 4 through 7. The drift cooling step may be greatly reduced or eliminated if retrieval operations are relatively continuous.

If an abnormal condition is found to be present in the emplacement drift, there are several options which can be considered. One is to continue the normal retrieval process in other locations of the repository while addressing the abnormal condition encountered. An abnormal operations plan could then be implemented while normal retrieval continues in other areas. The interim layout offers sufficient flexibility to operate under such a plan.

A second option, which may only be practical if the abnormal condition represents a serious condition throughout the repository, would be to suspend all normal retrieval operations until the abnormal condition is mitigated.

8.12.3 Abnormal Retrieval Conditions and Operations

For those areas where abnormal conditions are assessed, abnormal retrieval can be summarized, using the interim layout and the ISDOR emplacement concept for purposes of example, according to the following operational steps which are shown in the flowchart of Figure 8.12-1:

- Step 8 - Assess Nuclear Safety

  Once access to the emplacement drifts has been achieved and abnormal conditions are found, as assessment of the nuclear safety aspects of abnormal retrieval is necessary. This assessment must determine to the extent possible by the abnormal condition(s) whether radionuclide release(s) will be a factor in abnormal retrieval operations. A radionuclide release would indicate that there is a problem with one or more containment barriers provided by the WPs. It should be noted that a determination of this as a credible event has not been made to date, but this aspect is included in this preliminary operations concept to address the need for such work. Such a release would cause elevated radiation levels within the emplacement drift beyond those expected from intact emplaced WPs and would also indicate a need to contain the radionuclides and other contaminated items as a part of the retrieval operation.

- Step 9 - Develop Abnormal Retrieval Plan to Address Conditions
  Most retrieval operations functions that must be performed under abnormal conditions are fundamentally the same as normal operations, with the exception that an "abnormal" condition is defined as when the retrieval process must be performed with non-standard equipment or procedures. The existence of an abnormal condition may not necessarily mean that retrieval is impossible or particularly hazardous; rather, it means that modified equipment or procedures may be used. If an abnormal condition exists within the subsurface repository environment, predeveloped or specially prepared plans, depending upon the abnormal condition(s) present, may be used to address the abnormal condition(s). In the event of a radionuclide release associated with an abnormal condition, retrieval plans must also address the containment and disposal of radionuclides and other contaminated material in addition to retrieval of the WPs themselves. In some cases, such as contaminated water in a flooded drift for example, treatment of the contaminated material (i.e., the water) by special equipment and procedures would be necessary and must be included in the development of a retrieval plan.

- Step 10 - Provide Special Equipment Required

  The necessary special equipment required to implement the abnormal operating plan(s) will be procured, as required. It should be noted that during the course of retrieval operations, one or more combinations of abnormal conditions may be encountered, which may require differing special operating plans, equipment, or procedures to be used. Both special equipment and procedures will be tested during this period, all applicable to the condition(s) present.

- Step 11 - Implement Abnormal Retrieval Operations

  Both prior to and during the course of abnormal retrieval operations, abnormal conditions may be precipitated by processes and events such as tectonics, variability in rock characteristics, human error, or aging and corrosion of equipment and facilities. Abnormal retrieval operating plan(s) to provide access to the WPs, and remove them from the emplacement drifts will be implemented as appropriate to the conditions present.

- Step 12 - Prepare Emplacement Drift to the Extent Allowed by Abnormal Condition

  As discussed in Step 4, one major aspect of emplacement drift preparation is cooling. Forced-air cooling of the previously unventilated emplacement drift with large quantities of ambient air will be used just prior to the time that reentry is necessary (see Section 8.12.5). However, an abnormal condition within the emplacement drift may prevent the drift from being fully cooled by normal, flow-through ventilation as a cooling procedure. This step in the abnormal retrieval operation would allow for cooling of the emplacement drift to the maximum extent practical using normal procedures. Special procedures and equipment may be used to achieve a fully cool opening. Other preparation aspects could include repair or replacement of permanently installed fixtures in the drift needed for the retrieval operation that have deteriorated beyond a usable condition. Potential fixtures are as described in Step 4.

Several abnormal conditions, precipitated by the processes and events described earlier, are presented to provide an example of a preliminary approach to abnormal retrieval using the ISDOR emplacement concept and the interim layout. The abnormal conditions include the following:

- **Flooding of the emplacement drift** - Potentially caused by blockage of drains at the emplacement drift entrance if allowed to go unmaintained over a long period. Flooding of the drift may also prevent normal drift cooling procedures to be used.

- **Excessive drift temperature** - Potentially caused by a drift fully or partially blocked by rockfall preventing or impeding normal flow-through ventilation cooling.

- **Emplacement drift blocked by rockfall** - Potentially caused by deterioration of ground support components in the opening in-between WPs.

- **WP buried or lodged in the drift by rockfall** - Potentially caused by deterioration of ground support components in the opening over a WP.

- **Emplacement cart derailed** - Potentially caused by a seismic event, deterioration or deformation of the supporting rail, or by a large rockfall in the drift onto or against the WP. Also potential for this occurrence during normal retrieval operations when the WP is being transported to the emplacement drift entrance.

- **Emplacement cart unmovable** - Potentially caused by rusted emplacement cart wheel bearings or wheels rusted to the rails.

The above conditions have been identified by engineering judgment, and have not yet been established by statistical analysis techniques as credible events. They are presented at this time only for clarity of the logic discussed in this Section.

Figure 8.12-1 provides a preliminary example of the logic that would be followed to address the above conditions. As can be seen from the flowchart, each condition may require a special plan of operations, procedures, and different operating functions from special equipment. These items require further investigation during ACD. Each abnormal occurrence may or may not involve a release of radionuclides as a result of the abnormal condition. As can be seen from Figure 8.12-1, a radionuclide release would affect the plans, procedures, and equipment necessary to accomplish retrieval.

It should also be noted that one, or possibly a combination of the above mentioned abnormal conditions may be present in a single emplacement drift. The logic flow in Figure 8.12-1 presents the order of priority that would likely be followed as each WP is removed from the emplacement drift in a repository configured similar to the interim layout. Also, at any time during the retrieval operation, retrieval equipment failure could result in a normal retrieval operation changing to an abnormal operation.

8.12.4 Retrieval Equipment Considerations

Mobile emplacement equipment used for normal retrieval in the ISDOR concept consists of four primary items: (1) an electric trolley powered locomotive used in main drifts and ramps; (2) a movable rail turntable used in the waste handling main; (3) a shielded rail transport cask used in main drifts and ramps; and (4) a battery powered, remotely operated, locomotive used in the emplacement drifts.

Other mobile support equipment needed during the retrieval period include rail transporters (M&O, 1994m, Key 010, Key 030) for personnel, and minor supplies and equipment used for routine maintenance.

The availability of original mobile emplacement equipment for normal retrieval operations will, to a great degree, be dependent upon the duration of the emplacement period and the condition of the equipment after that period. Maintenance of emplacement equipment during the emplacement period will consist of normal routine maintenance, and scheduled equipment rebuilds or replacement as total-life-cycle-cost economics dictate.

Retrieval of all the WPs is required in a reasonable schedule mandated by 10 CFR 60 - "about the same time as that devoted to construction of the GROA and the emplacement of wastes" (10 CFR 60.111(b)(3)). Under past estimates made for the SCP-CDR conceptual design, the construction and emplacement period could last for a period up to 34 years. While no overall repository construction and emplacement schedules have been developed for the interim layout using small drift emplacement, retrieval should be easily achieved in a time frame similar to the SCP-CDR, although it may require several suites of equipment.

It is unusual to find mobile equipment operating in an underground environment for a period longer than 10 to 20 years, even if such equipment has been operated under good maintenance practices. The reasons for this are normal deterioration, equipment obsolescence, or unfavorable economics when considering further existing equipment maintenance compared to replacement. The conclusion that can therefore be drawn from the above emplacement time frame is that there would be a high probability of a need for new mobile equipment at the start of retrieval operations. This statement should hold true regardless of at what time during the 100 year period of retrievability the start of retrieval operations would begin.

For a retrievability period of up to the statutory 50 year length after first emplacement, it is reasonable to assume that mobile equipment used for normal retrieval operations will be of the same or similar design as that used when emplacement operations were completed (or suspended, as applicable). The rationale for this statement is that the end of such a retrievability period may only be approximately 16 years (the 50 years minus the 34 years to construct and emplace). It is also possible that replacement equipment procured during the emplacement period may have been upgraded, making the equipment technology used at last emplacement reasonably current at the time of retrieval.

For a retrievability period beyond the statutory 50-year period and up to 100 years in length, available material handling equipment and methods at that time will have likely advanced significantly beyond current technology. Therefore, for retrievability periods beyond 50 years and up to the current assumption of 100 years in the CDA (M&O, 1994m, Key 016), it is reasonable to assume that technology of the time will be examined for use in retrieval operations. The rationale for this statement is that the cost and safety implications for using out-dated, although by then well-proven technology, must be compared with the cost and safety improvements that could be available using state-of-the-art equipment available at that time.

Certain stationary plant equipment including surface and subsurface ventilation fans, dewatering pumps, and permanent utilities associated with subsurface operations will be necessary to support both performance monitoring activities and retrieval operations. Fans and pumps will be required to operate to some degree throughout the emplacement and caretaker periods, and consequently, will be rebuilt and replaced at somewhat regular intervals. Utilities in main access drifts and other access openings into the repository will require periodic routine maintenance and selected replacement when deteriorated or damaged beyond a condition of reasonable and economic repair.

8.12.5 Retrieval Ventilation Considerations

The CDA states that the repository will be designed for a retrievability period of up to 100 years after initiation of emplacement (M&O, 1994m, Key 016). To satisfy this objective, the repository underground ventilation system must be designed so that acceptable climate conditions can be provided to support the retrieval activities. The CDA specifies that the air temperature in emplacement drifts during retrieval shall not exceed 50°C (M&O, 1994m, DCSS-019). Ventilation is perhaps the most effective temperature control method. Two primary concepts of ventilation for retrieval are being considered:

Continuous Ventilation: continuously ventilating all of the emplacement drifts, beginning at the time of emplacement and continuing throughout the pre-closure period (ventilation fixtures could be incorporated into the radiation doors to facilitate ventilation while maintaining shielding);

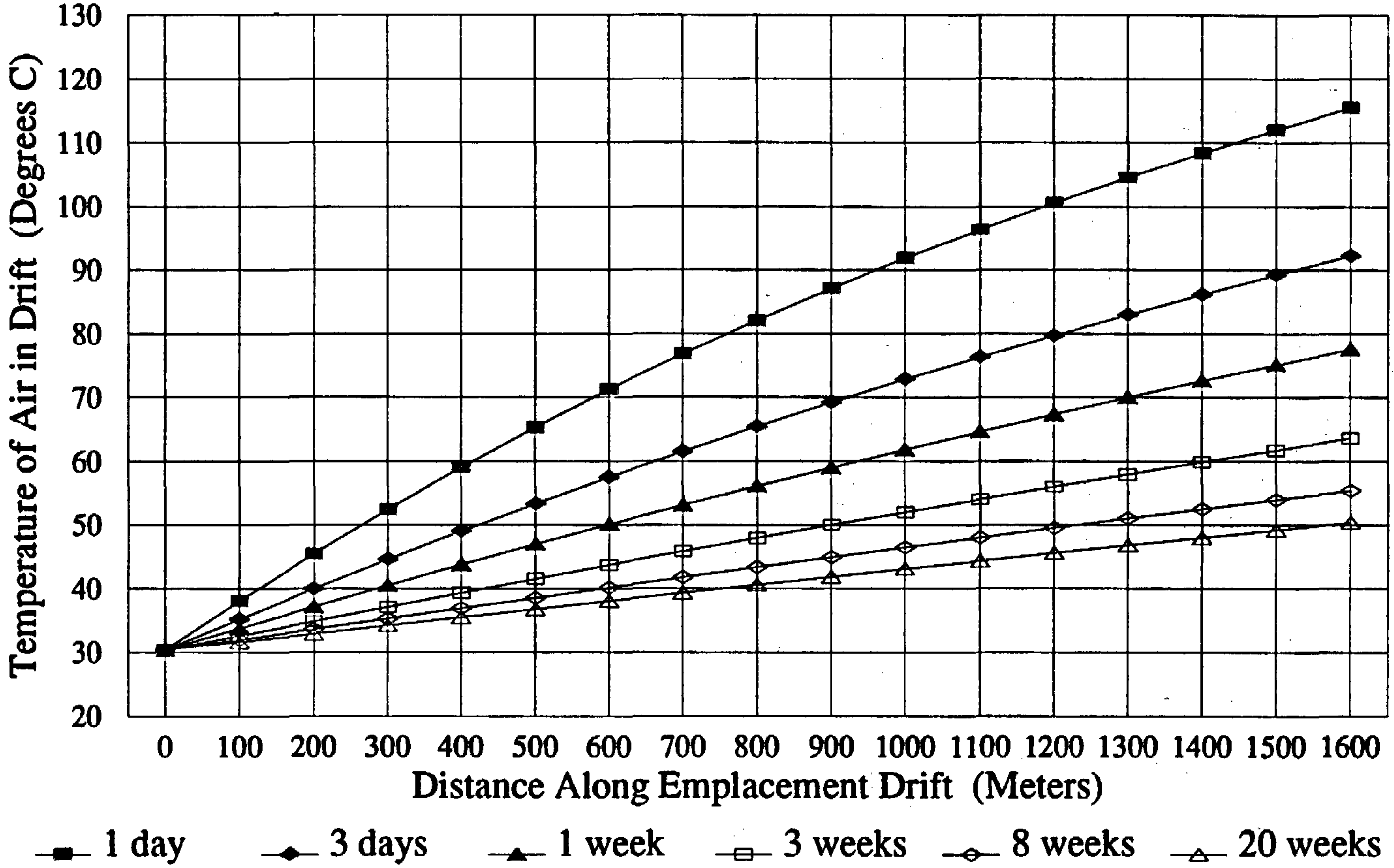
Ventilation as Needed: after completion of waste emplacement, keep the emplacement drifts unventilated; when drift accesses are needed for required operations (such as waste retrieval or performance confirmation), cool the previously unventilated drifts with large quantities of ambient air just prior to reentry. This ventilation mode is also frequently referred to as rapid cooling, forced-air cooling, or blast cooling.

The Subsurface Ventilation Concepts Report for Repository ACD-FY 1994 (M&O, 1994q) analyzed the feasibility of both types of cooling by ventilation, and performed preliminary calculations for temperature in emplacement drifts of the interim layout concepts. The following discussions of ventilation for retrieval of emplaced waste are based primarily on that study and use an air temperature of 50°C (M&O, 1994m, DCSS-019) as representative of acceptable working conditions during the potential retrieval process.

The drift temperature under continuous ventilation is a complex function of ventilation air flow rate, time of ventilation, drift configuration, rock properties, heat load, emplacement mode, and so on. This long term transient state heat transfer process involves conduction, convection, and radiation. Preliminary investigations have indicated that it is feasible to maintain the accessibility of an emplacement drift for an extended period by providing ventilation continuously. Continuous ventilation removes heat from the repository from the beginning of the heat transfer processes, thus a relatively low drift temperature is expected in comparison to that in an unventilated drift. However, this approach requires an extremely large total air quantity because all of the emplacement drifts are ventilated simultaneously. Calculated examples for the interim layout show that to maintain the temperature of ventilating air in an emplacement drift below 50°C, using intake air at a temperature of 30°C, the air flow rates required are up to 30.81 m^3/s for a 1235 m long drift. This illustrates that ventilation air flowing in what could be considered a normal range would be capable of continuously removing the desired amount of heat from a single emplacement drift without exceeding the 50°C temperature. However, simultaneously ventilating all emplacement drifts requires a very large total air quantity (i.e., up to 4800 m^3/s for the upper block in the interim layout); consequently, excessive costs for ventilation related construction and operation could be expected and additional shafts might be needed. Further study of alternate ventilation cooling concepts is recommended before seriously considering continuous ventilation as a viable option.

When a drift emplaced with waste is unventilated for an extended period such as 100 years, the heat transfer from the waste to the surrounding rock, mainly through conductive and radiative processes, will cause a large scale increase in rock and drift wall temperatures. This is because the drift has been sealed from ventilation and almost all of the energy released from the waste is transferred to its surroundings. Cooling an emplacement drift under these circumstances within a reasonable period of time requires a relatively large quantity of air for a single drift when compared to the continuous ventilation case, due to increased temperatures of the drift wall and surrounding rock mass. However, the total air quantity required is substantially reduced because the number of drifts undergoing cooling at a given time would be reduced. The maximum initial rock temperature at the beginning of cooling depends on factors including thermal loading, emplacement mode, rock properties and drift configuration. For a given initial rock temperature, the quantity of ventilation air becomes the predominant factor in temperature control. Transient state calculations and analysis (M&O, 1994q) show that it is possible to regain access to an emplacement drift that has been closed for an extended period by ventilating the drift with large quantities of ambient air.

Figure 8.12.5-1 provides an example of the temperature distributions along an emplacement drift and their variation as a function of the time of cooling. A typical air quantity of 150 m^3/s was selected to illustrate a complete emplacement drift cooling process to a temperature of 50°C. As shown on the figure, the air temperature steadily increases while passing through the drift, due to the high initial rock temperature. The highest air temperature always occurs at the airway exit. Based on the parameters stated on the plot, to reduce the air temperature to 50°C for reentry, it takes about a day for the first 400 meters of the drift, and three days for the first 600 meters. After about a week of ventilation, the first 900 meters of the drift would become accessible. For an emplacement drift 1300 m long, the maximum air



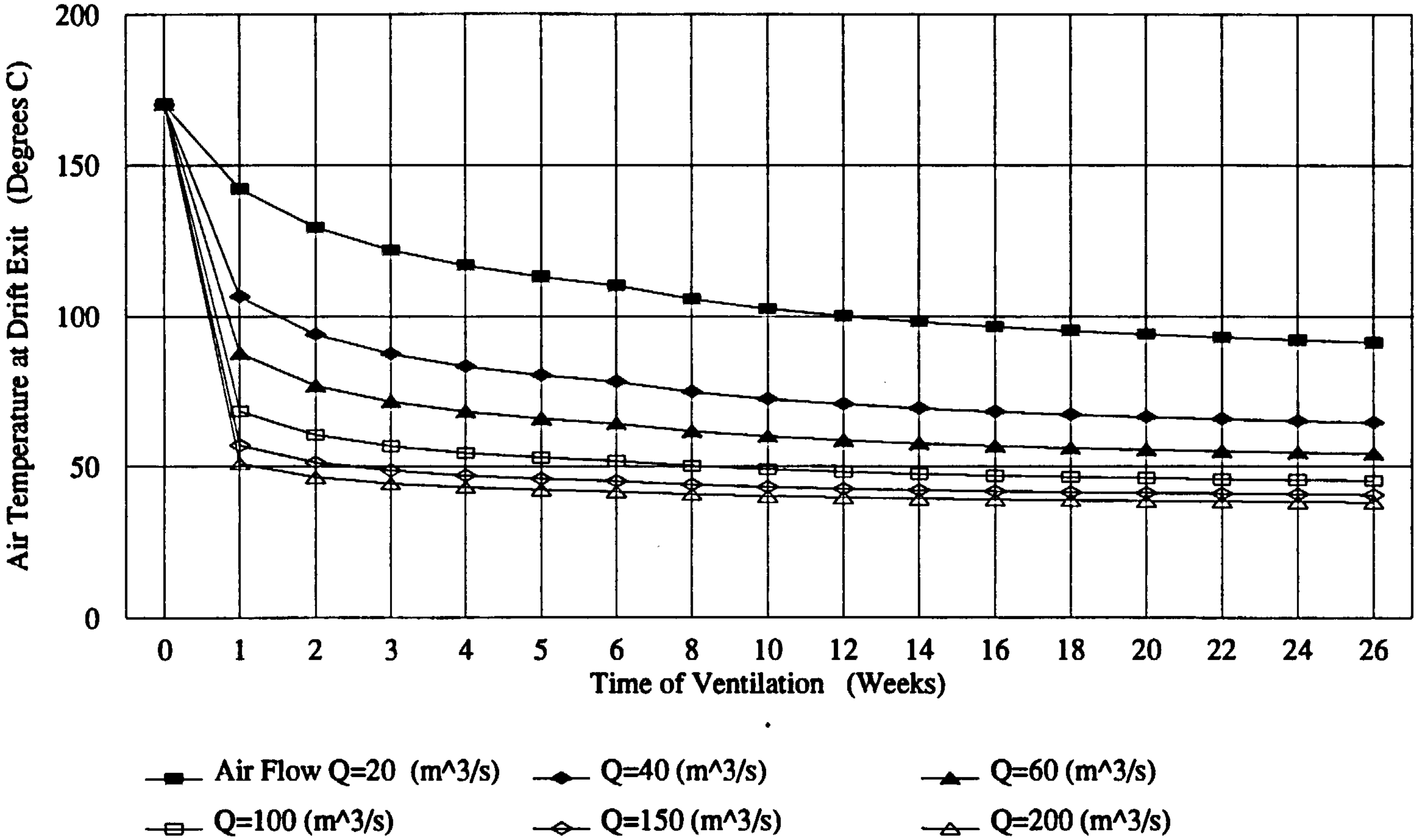
* Calculated for: 1) In-drift emplacement, 2) Airflow rate 100 cubic meter per sec. 3) Drift diam. 5.0 m,

4) Intake air temperature 30.3 C, and 5) Initial rock temperature of 170 C at beginning of ventilation. [File:"FIG118.794" - h.yang]

Figure 8.12.5-1. Temperature of Ventilating Air Along an Emplacement Drift During the Cooling Period temperature (occurring at drift exit) can be reduced to below 50°C in less than three weeks of rapid cooling. To reduce the maximum temperature of a longer drift (1600 m) to 50°C, six weeks of cooling time will be necessary.

The highest temperature profile in the initial stage of cooling indicates that the highest heat load on the air flow occurs at the beginning of the cooling. During the period of ventilation, the heat load on the air flow is reduced at a decreasing rate. This type of behavior reveals the importance of the initial air quantity at the beginning of drift cooling. It would be advantageous to provide very high air flow quantities initially for rapid and effective cooling. After the heat transfer rate is reduced, a lower air quantity could be used to maintain the desirable drift temperature. This suggests the possibility of using a staged approach for concurrently cooling additional drifts in order to reduce the total air quantity requirement

Figure 8.12.5-2 presents the calculated temperatures of air exiting emplacement drifts during cooling, based on various air quantities and cooling times. For a 1235 m long drift and other parameters shown on the figure, the temperature profiles demonstrate that an air flow of 150 m^3/s can reduce the temperature of air exiting the drift to below 50°C after two and a half weeks of cooling by ventilation. Cooling with an air flow rate 100 m^3/s can also provide the allowable temperature level along the entire drift length within a little longer but still acceptable period of time (about 8 weeks). If a very high air quantity of 200 m^3/s is used, access to the entire drift is possible within the first week of ventilation. For air flows equal to or lower than 60 m^3/s, it is impossible to reduce the air temperature at drift exit to 50°C within 26 weeks.



* Calculated for: 1) In-drift emplacement, 2) Emplacement drift length 1235 m, 3) Drift diam. 5 m,

4) Intake air temperature 30.3 C, and 5) Initial rock temperature of 170 C at beginning of ventilation. [File:"FIG119.794" - h.yang]

Figure 8.12.5-2. Air Temperature at Drift Exit During the Cooling Period

9. CLOSURE AND DECOMMISSIONING

9.1 SUBSURFACE CONSIDERATIONS

Closure and decommissioning of subsurface related facilities will occur after the period of retrievability, currently established as 100 years after first emplacement (M&O 1994m, Key 016). In general, subsurface activities related to repository closure will involve sealing of the ends of emplacement drifts; the removal, to an extent practical or safe, of utilities, structures and equipment from the subsurface environment; backfilling of major subsurface access drifts on the repository block; and backfilling and placement of seals in all shafts and ramps. In addition, the placement of backfill in the emplacement drifts is an option that will be available at closure and is discussed in greater detail in Section 9.1.1.

Activities planned at decommissioning relate primarily to the decontamination and dismantling of surface facilities and the surrounding site. Of the surface structures and facilities, several will be related to subsurface operations including the shaft collars and ramp portals, and associated facilities such as mechanical ventilation plants, air ducts, and hoisting facilities.

ACD activities related to a majority of the above areas were not included in the FY 1994 scope of work; consequently, these topics will be addressed in greater detail as ACD progresses. Backfill placement in the emplacement drifts was included in the scope of work and is summarized in Section 9.1.1.

9.1.1 Backfilling and Sealing of Emplacement Drifts

Backfill in the emplacement drifts could be placed for four major reasons: (1) to prevent deleterious rock movement in the strata between the surface and the repository horizon which may cause surface subsidence; (2) to provide a pre-determined environment around waste packages to enhance the long-term performance of the waste package exterior; (3) to protect, or cushion, the waste package from damage caused by rock falling onto the waste package; and (4) to retard the transport of radionuclides to the accessible environment.

The choice of whether to backfill the emplacement drifts at closure is an option that will be available to repository operations management (DOE). However, placement of backfill in the emplacement drifts is neither required nor prohibited by regulation, and the current Yucca Mountain Project position is that no backfill will be used in emplacement drifts (M&O, 1994m, Key 046). The rationale for this position is that since no performance requirement is currently allocated to backfill, the waste package will be designed to withstand expected rockfall during the substantially complete containment period, and it will be difficult and expensive to emplace backfill.

As with all controlled assumptions, the validity of the assumption not to backfill an emplacement drift must be substantiated during ACD. As a part of this process, backfill concepts and operations were examined on a preliminary basis in FY 1994. The interim layout formed the basis for the examination of concepts.

Investigations of emplacement drift seals were not included in the FY 1994 scope of work.

9.1.1.1 Backfill Materials and Selection Considerations

Potential materials available for use as a backfill for a horizontal, in-drift emplacement configuration include dry materials, concrete, and hydraulic slurries. However, preliminary conclusions presented by the Waste Package Development group (M&O, 1994r) regarding backfill are that the most promising backfill strategies are to use no backfill or to use crushed tuff, possibly with an additive for controlling water chemistry. Any additives must be chosen to avoid harmful effects of microbial growth which might enhance waste package corrosion rates. This section of the report therefore provides its remaining focus on some of the preliminary aspects of dry crushed tuff backfill placement. General materials and operations considerations related to other backfill materials can be found in a 1994 M&O report (1994b).

Recent studies (Conca et al., 1993; M&O, 1994r) have examined the use of a coarse material (gravel) placed near the waste package, with a sloping layer of fine material (sand) placed on top of the coarse material. Because of capillary forces, water that drips onto the fine particles will be held in the small pores and will not penetrate into the larger gaps in the coarse layer as long as unsaturated flow conditions exist. Sloping the fine layer down at the sides will direct water to the sides of the drift. To achieve an effective diversion requires a sharp interface to be present between the two layers. It also requires no dips or low spots in the interface. The benefits of a two-layer backfill, however, have sometimes been overstated in the technical literature with the fine layer described as if it were impermeable (M&O, 1994r). To successfully construct a sharp interface between the coarse and fine material layers in a potentially harsh environment (temperatures and radiation) by remote control or automation is a significant consideration.

Table 9.1.1-1 shows an example of the material size distribution for such a gravel and sand backfill and is included for reference with respect to discussions in Section 9.1.1.3 on backfill placement operations and quality.

Table 9.1.1-1. Example Size Distribution for Gravel/Sand Dry Backfill Barrier System

Gravel		Sand	
Sieve Size (mm)	Weight % Passing Sieve	Sieve Size (mm)	Weight % Passing Sieve
25	100	2.5	90 - 100
19	75	0.25	0 - 5
13	40		
9.5	10		
3	5		

After Conca et al., (1993)

9.1.1.2 Dry Backfill Placement Considerations

At Yucca Mountain, conventional underground backfilling techniques must address a set of physical placement and quality considerations which could be quite different than typically seen in the underground mining or construction industry. Backfill placement methods at Yucca Mountain must address difficult problems such as placing material in long drifts, potentially remotely, and under potentially high temperatures and radiation levels (although greatly reduced from levels at the time of emplacement). As a further complicating factor, if backfill in the emplacement drifts were needed to enhance the performance of the engineered barrier system, such as providing a water infiltration barrier, placement of a backfill with predictable and consistent emplaced properties, such as gradation and compaction, will be a key consideration.

In general, dry backfill can be placed using mechanical or pneumatic methods. The method or combination of methods is determined by the performance requirements of the backfill material, by the physical characteristics of the drift (clearances, temperature, and radiation) and by the physical limitations of the equipment and backfilling operation. For reasons discussed below, this report briefly discusses mechanical backfilling but focuses the majority of attention on placement by pneumatic backfilling systems.

Mechanically Placed Dry Backfill

Mechanically placed fill can involve techniques ranging from simple dumping by conveyor or other similar types of spreading equipment with poor compaction and support characteristics of the fill. Placement of fill can also involve the use of specialized mobile machinery to provide excellent compaction of a fill. The above assumes a sufficient operating environment and operating clearances are available, which will generally not be available in the emplacement drifts.

The use of a conveyor to place a dry backfill followed by vibro-compaction is a method that may be feasible. Vibro-compaction is the rearrangement of particles into a denser configuration by the use of powerful depth vibrators. Depth vibrators are long, cylindrical, probe-like devices that are penetrated into a backfill medium and cause the backfill material densification process to occur. A small scale application of vibro-compaction is commonly used to compact dry ballast placed under ties used with railroad tracks.

This method would only be suited to an application requiring partial drift backfilling, or a bottom layer of backfill, because of the difficulty of placing backfill above the conveyor return belt line. Additionally, for conveyor emplaced backfill to be feasible, the drift must be cool enough and radiation levels must be low enough to permit reliable operation of susceptible mechanical conveyor components. Sufficient clearances must also be present to allow passage of the conveyor and vibro-compaction equipment. One significant drawback to this method would be if a mechanical failure or belt break were to occur somewhere in a long (1,200 m) emplacement drift. An idle, loaded belt would result, making recovery from such a breakdown difficult by remote means.

Pneumatically Placed Dry Backfill

Pneumatic backfill placement involves the transport and emplacement of fill material by air pressure.

Two types of pneumatic conveying systems have been developed: 1) low pressure, continuous air equipment (a dilute-phase system); and 2) high pressure, pulsating air equipment (a dense-phase system). With the dilute-phase system, the characteristics of the backfilling operation and in-place backfill are similar to hydraulic techniques. Dense-phase systems use intermittent blasts of material at high velocity but are less popular because of increased pipe wear resulting from high transport velocities and ricochet problems with the backfill material during deposition.

A typical dilute-phase, commercial pneumatic conveying system consists of four essential elements (Powell, 1982):

- A source of pressurized air, often supplied by a blower-compressor
- A regulated infeed to introduce the backfill material into the pressurized airstream, often achieved by the use of a rotary-airlock-feeder
- A pipeline to convey the air and material to the desired location
- A discharge piece to direct the material as it leaves the pipe, with varying degrees of control depending upon the application.

The capacity of commercially available pneumatic conveying systems commonly used to place backfill underground is from 90 to 450 tonnes/hour.

As the throughput of the system increases, larger or alternately multiple pipelines must be used to prevent excessive system air pressure drops. In emplacement drifts, permanently installed support components for large or multiple pipes could tend to increase drift size to prevent interference with waste package emplacement equipment, such as the gantry concepts discussed in Section 8.7.2. Many kilometers of larger emplacement drifts, strictly to accommodate high backfill emplacement rates, would not be a cost effective approach. In general, it would be more prudent to size the throughput of a pneumatic system in the repository for one in which a single, reasonably sized pipe would suffice.

In repository emplacement drifts, the presence of waste packages makes the potential for remote backfilling operations and the good compaction of backfill that can traditionally be obtained by pneumatic methods in open drifts very uncertain. Multiple pipes may be required, even at reasonable emplacement rates, to achieve a particular backfill density within an emplacement drift filled with waste packages and associated supports. This aspect is discussed in Section 9.1.1.3.

The question of the insulating properties provided by a poorly compacted backfill, if such a fill were to result, and its effect on waste package performance, must also be addressed when considering the applicability of a pneumatically placed backfill at Yucca Mountain.

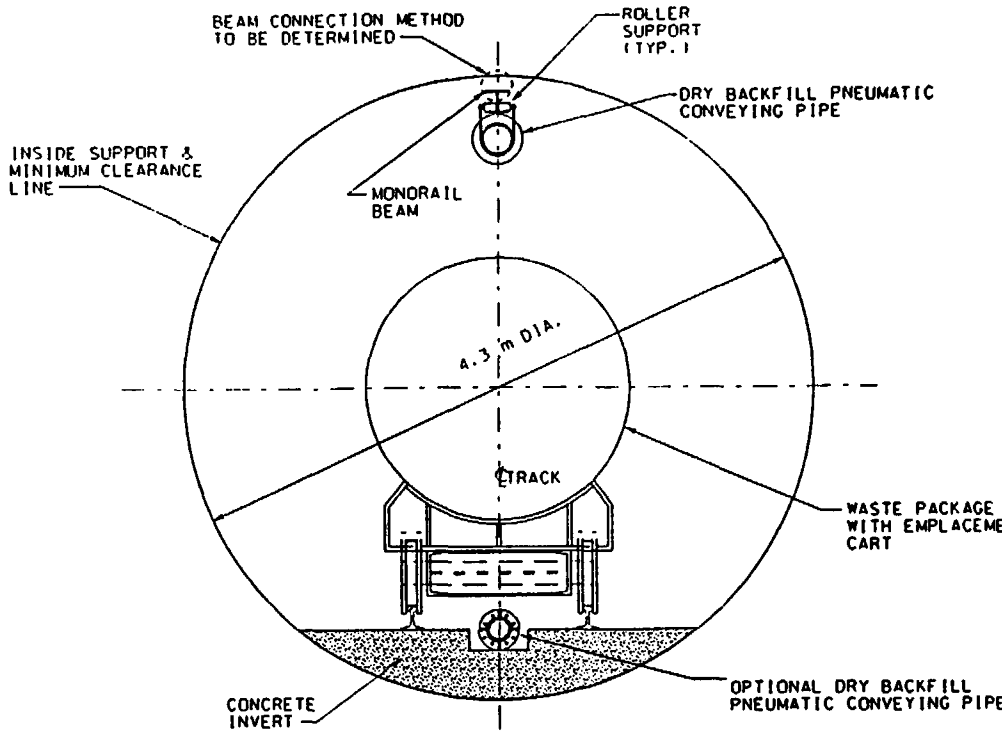
9.1.1.3 Preliminary Concept for Placing Dry Backfill in an Emplacement Drift

A preliminary concept of operations for pneumatic placement of a backfill configuration consisting of the coarse material and sand size distribution shown in Table 9.1.1-1 is presented as an illustrative example. The methods of producing and placing such a backfill, along with the potential placement results, are discussed. The concept presented assumes the ISDOR emplacement concept and a long (1,200 m ±) and straight emplacement drift which is representative of the interim layout.

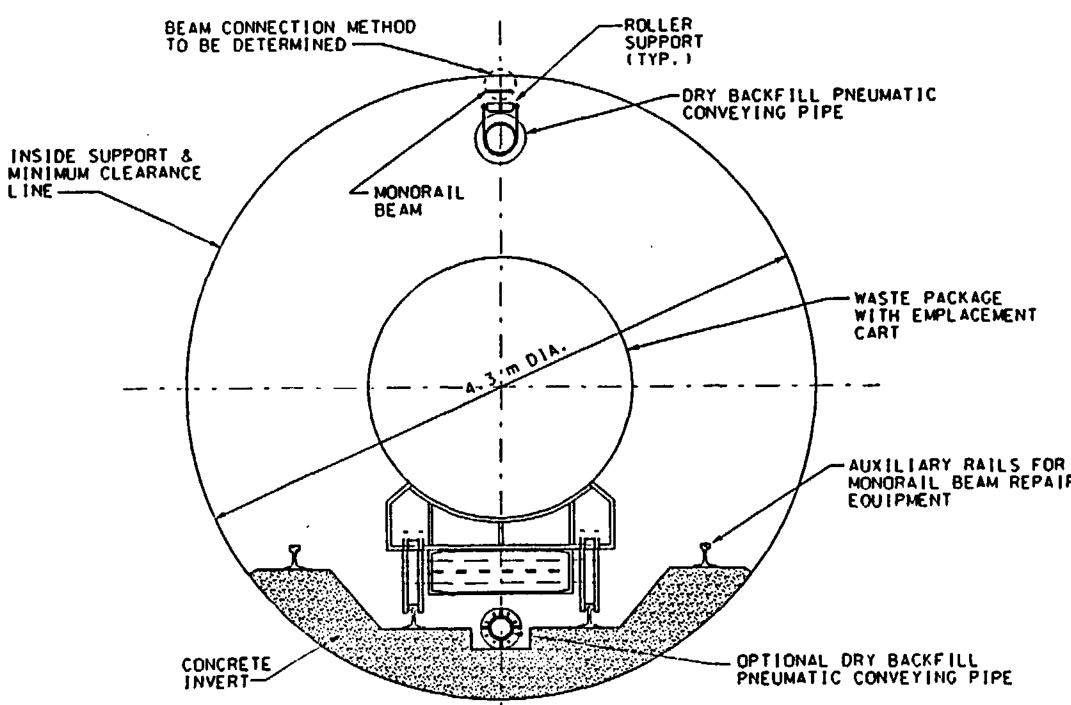
During the repository construction phase, a monorail support beam would be installed in each emplacement drift to facilitate future backfilling operations as shown in Figure 9.1.1-1. The beam would be designed with connections to allow careful alignment. A second function for this beam could be as a trackway for performing routine monitoring (such as with a camera) of drift conditions throughout the operational and caretaker phases of the repository.

At the time that backfill is to be placed, which could be 100 years after the first waste package emplacement, a remotely controlled camera would travel the full length of the monorail beam to inspect it for damage, corrosion, or misalignment.

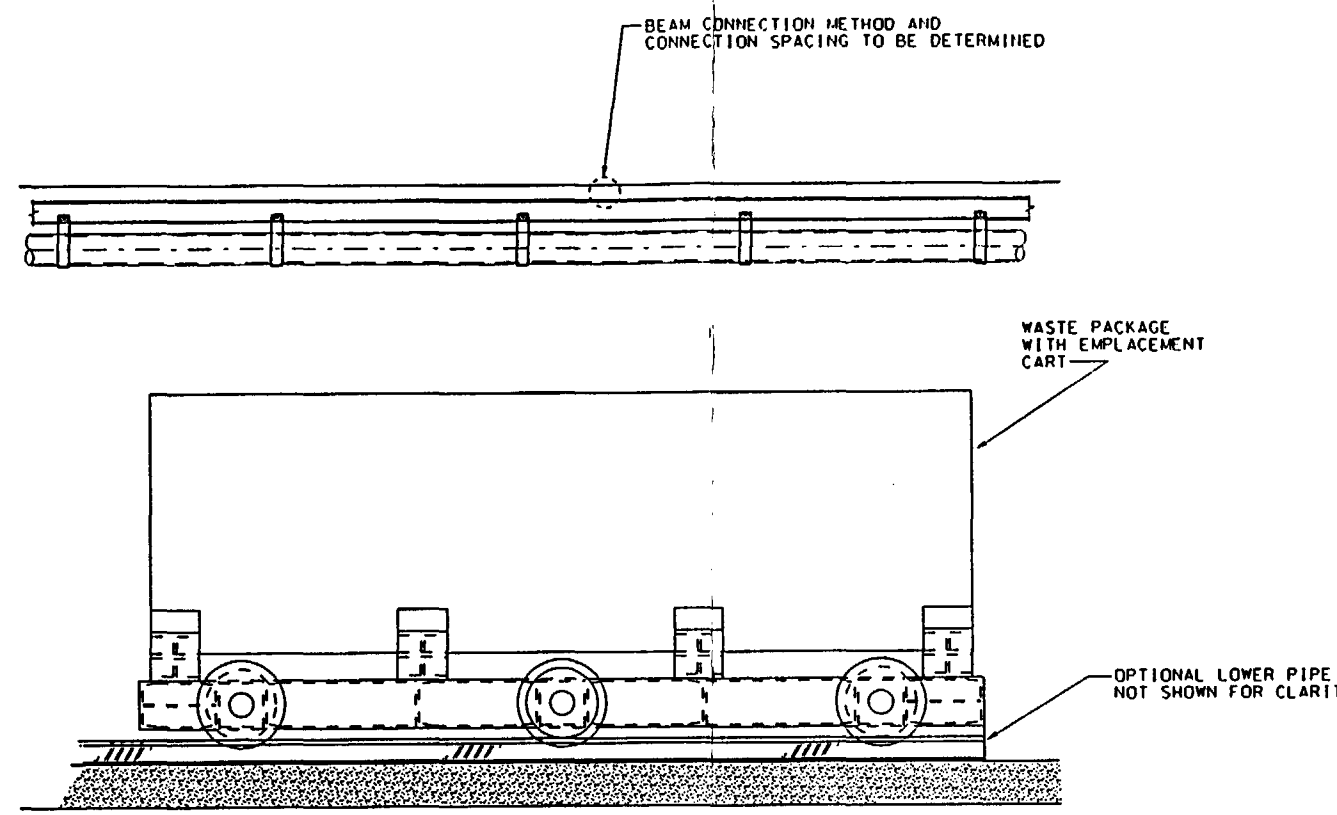
If damage or misalignment is found, one option for beam repair or replacement would be to use a special piece of equipment with robotic mechanical arms that would travel over the waste packages. In this case, if the waste package is placed atop a permanent rail emplacement cart, a second set of rails would need to be permanently installed in the drift as shown in Figure 9.1.1-1. To achieve the required operating clearances at the invert for a second set of rails, the invert would need to be raised to be located nearer to the tunnel's center, or a larger tunnel would need to be excavated. In Figure 9.1.1-1, a 4.3 m operating clearance line is shown for illustrative purposes. As can be seen, clearances for operation of



MONORAIL REPAIRS REQUIRE
WASTE PACKAGE REMOVAL



MONORAIL REPAIRS DO NOT REQUIRE
WASTE PACKAGE REMOVAL



SIDE ELEVATION

Figure 9.1.1-1

PNEUMATIC BACKFILLING IN
EMPLACEMENT DRIFTS
(RAIL EMPLACEMENT MODE)

DRAWN R REGAN	DESIGNED M GRIGORE
	CAD FILE SSRM-SK102.DGN

regan /proj/repss/mine/dgn/ssrm-sk102.dg

such a robotic device would be limited, and an operating envelope greater than 4.3 m may in all likelihood be required for such a device.

A second option in lieu of a robotic piece of repair equipment would be to remove all waste packages from the drift up to, and a safe distance beyond (from a radiation exposure standpoint), the damaged area. Repairs could then be accomplished using more conventional techniques, possibly with the use of temporary shielding since radiation levels within the drift would be reduced after 100 years.

In either of the above two options, drift cooling would be needed prior to inspection and repair. The second option (partial or full retrieval from a drift) may be a more realistic option for small emplacement drifts in the 4 to 5 m diameter range because of the limited working clearances that are available, as Figure 9.1.1-1 indicates.

After the monorail beam has been checked (and repaired if necessary), one or more pneumatic backfill pipes would be installed in the drift. As a minimum, one bolted flange pipe would be installed in the crown of the emplacement drift for a distance of 600 m ± from the TBM launch main drift. An alternate method of coupling may be to use shouldered pipe joints with quick-disconnect (such as a lever) mechanical couplings which is a common method of connecting concrete slicklines. The conveying pipe would be designed to travel on the monorail beam via roller supports attached to the pipe as shown in Figure 9.1.1-1. A 200 mm nominal diameter pipe is shown in that figure. The conveying pipe would be assembled in 6 m long sections from the TBM launch main drift as shown in Figure 9.1.1-2.

A second 600 m ± long conveying pipe would be installed in the drift crown by identical means from the opposite end of the emplacement area (i.e., perimeter main drift); thus, the full 1,200 m ± drift length would be covered. Pipes would be run from both sides of the emplacement area because a 900 m total pipe length approaches the maximum economical length for pneumatic conveying systems commonly used underground (Powell, 1983).

An additional conveying pipe could also be installed in a pre-formed slot (either cast into a pre-cast invert segment or formed in a cast-in-place invert slab). Examples of a nominal 150 mm diameter lower pipe are shown in Figure 9.1.1-1. The lower conveying pipe is an option to aid in backfill placement in the narrow spaces under the emplacement carts. A reliable method of sliding the pipe couplings across expansion joints in the invert would be a critical consideration if a lower pipe is used. Skid bars welded to each side of the coupling would be one option to allow a coupling to slide across an expansion joint with less chance for hang-up.

The volcanic tuff excavated during repository construction will be a plentiful source for dry backfill material. A general size distribution of excavated tuff from TBM operations which would be stockpiled on the surface is shown in Table 9.1.1-2.

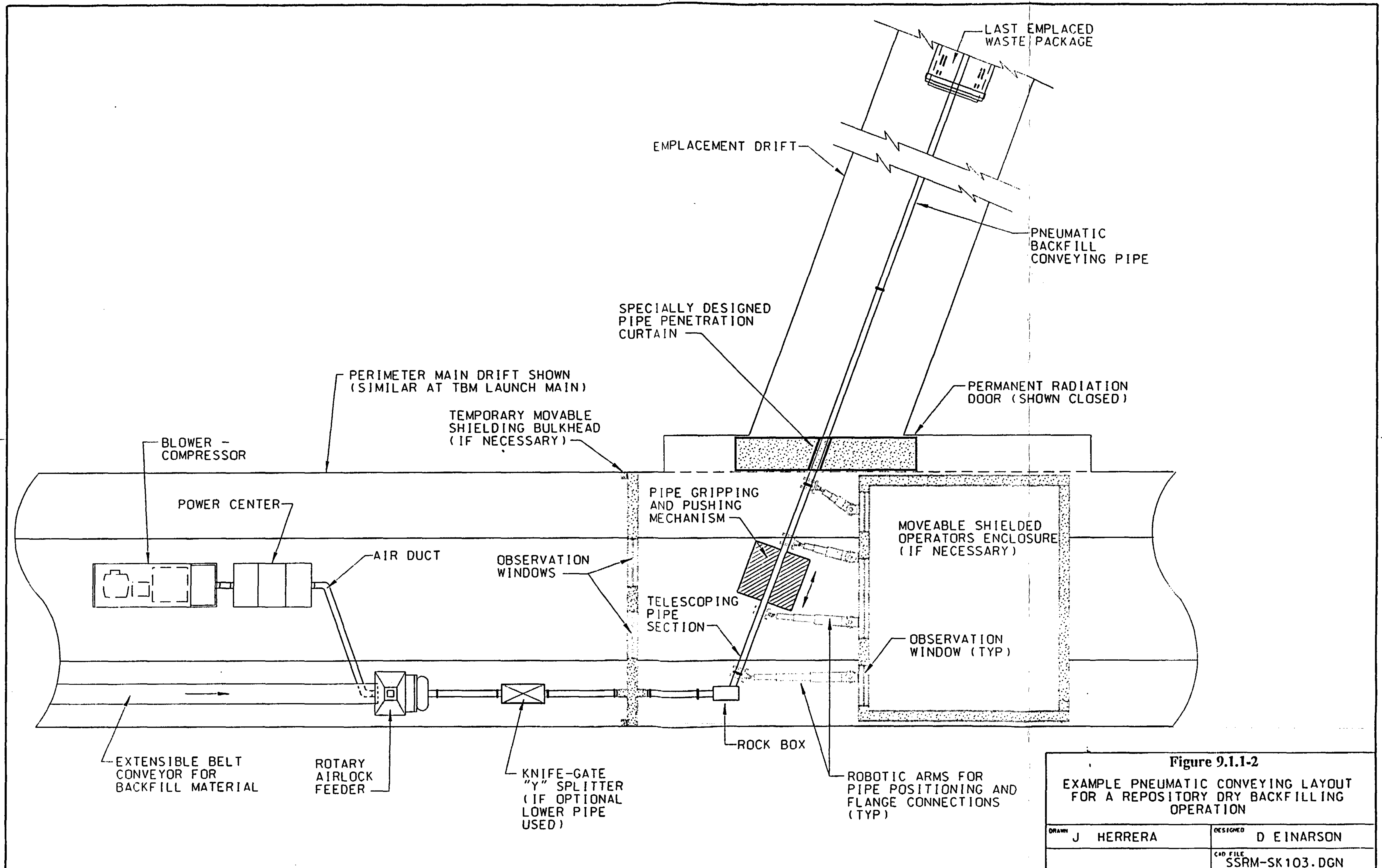


Figure 9.1.1-2
EXAMPLE PNEUMATIC CONVEYING LAYOUT FOR A REPOSITORY DRY BACKFILLING OPERATION

Table 9.1.1-2. Typical TBM Excavated Material Sizes

Screen Size (mm)	Weight % Passing
305	100
152	90
76	80
25	60
6	30

Modified from M&O (1993d)

A typical backfill placed pneumatically underground consists of material less than 100 mm in size, and a material in the range of 0 to 75 mm produces the greatest compaction (Powell, 1983). As can be seen, a majority of the material in Table 9.1.1-2 would be below 100 mm and would fall in the 0 to 75 mm size range. If this were the only requirement for a pneumatic fill, only simple screening of the oversized material would be necessary.

If a more specific material size distribution was required, such as the coarse and fine material shown in Table 9.1.1-1, for example, additional processing steps would be needed. As shown in the distribution in Table 9.1.1-1, it is also fully compatible with placement by pneumatic methods because all particle sizes are less than 100 mm. First, to obtain the coarse (gravel) material layer of Table 9.1.1-1, excavated tuff would be transferred from a surface stockpile and passed through a multiple-deck screening plant. The rejected material from this screening operation would be transferred to a separate stockpile for use as the fine (sand) material layer of Table 9.1.1-2.

Multiple-stage crushing and additional screening would be needed if sufficient coarse material was not obtained from the screening operation. As a minimum, primary and secondary crushing would be required, with a possible tertiary stage.

Fines from the screened reject stockpile (and/or multiple-stage crushing and screening operation, as applicable) would be used to achieve the sand shown in Table 9.1.1-1, but would require further screening and classifying to achieve the size distribution shown in that table. If sufficient fine material was not available from the above operations, additional stockpiled material would need to be fine-crushed, screened, and classified to obtain the remaining sand sizes required.

All of the screening and crushing operations described above can be combined into a single integrated operation using common modular "off-the-shelf" equipment used in the industrial minerals and hardrock mining industries. Washing or other material treatment processes could also be readily incorporated into such a plant if such items were necessary to ensure compatibility with the waste package materials or other long-term performance issues.

Once the material has been processed, it would be transferred down a repository shaft in two slickline pipes, one for the coarse (gravel-like) material and the second for the sand. Steel bins located at the base of the slickline pipes would provide some underground surge and storage capacity. The coarse material or sand, as needed, would be carried by a combination of conventional conveyors and two extensible belt (M&O, 1993d, pp. 5-17 to 5-20) conveyors from the shaft to the entrance of the emplacement drift to be backfilled. One extensible belt conveyor would travel to the appropriate emplacement drift via the perimeter main drift, and a second would travel to the appropriate emplacement drift via the TBM launch main drift.

The discussion below describes backfilling operations in the TBM launch main at the entrance to an emplacement drift, or in the perimeter main at the exit of an emplacement drift. If backfilling were performed many years after first emplacement, such as 100 years, the radiation emissions from the waste packages will be greatly reduced. However, detailed calculations necessary to establish what the actual radiation environment would be in these areas have not been performed to date. It, therefore, cannot be determined whether radiation levels would be significant enough to prohibit personnel from working in these areas unprotected by shielding. The following operations description example and equipment layout reflect the conservative viewpoint that radiation emissions from any penetration through a shielding door to allow clearance for items such as a backfill pipe could still be significant enough to warrant some amount of special equipment and shielding.

A minimum of two pneumatic conveying equipment setups would be required. One setup would be located at the TBM launch main drift and one at the perimeter main drift. An example of this equipment setup in the perimeter main drift is shown in Figure 9.1.1-2. The setup in the TBM launch main drift would be similar.

Penetrations are made through the closed radiation doors located at the ends of the emplacement drift, as shown in Figure 9.1.1-2. The penetrations in the radiation doors would be just wide enough for a pipe coupling or flanged joint to pass through with minimum clearance. The penetration would include a specially designed pipe penetration curtain to reduce radiation emissions through the penetration into the TBM launch or perimeter mains. However, as stated above for conservatism, some radiation emissions are still assumed to occur through this gap, and the entrance to the emplacement drift at the perimeter main (or TBM launch main) drift is thus assumed to be a radiation hazard environment. A movable shielded enclosure, equipped with several arms operated from within the enclosure is provided (again, for conservatism) to handle and couple new lengths of pipe. A temporary bulkhead in the perimeter main (or TBM launch main) drift would provide any additional level of required shielding to allow personnel to work around the pneumatic conveying equipment and feed conveyor without any further radiation safety precautions.

If a lower conveying pipe is used, a second pneumatic conveying setup at each location could also be installed to feed this pipe; or, more practically, a diversion "Y" with knife-gate valves could be connected to the two pipes, thus enabling a single set of pneumatic conveying equipment to be used. With the diversion "Y," the flow of backfill material could be alternated at will between the upper and lower pipes. An approximate position of the diversion "Y" is shown in Figure 9.1.1-2.

The backfill placement operation would be performed in a retreating manner from each end of the emplacement drift. A mechanism to grip the pipe string(s) and pull the string(s) out of the emplacement drift in a controlled manner would be located in the perimeter or TBM launch main as shown in Figure 9.1.1-2. The mechanism would also be used to initially push the pipe(s) into the drift.

One potential problem with a pneumatically placed backfill could be the difficulty in achieving a uniform and predictable gradation of particles if a backfill similar to that described in Table 9.1.1-1 is used. Due to the momentum of the backfill as it leaves the pipe, the coarser, heavier particles will be projected further out of the pipe and down the drift than the finer particles. If a backfill pipe is moved in 6 m increments, backfill materials may tend to segregate in zones by size increment along the longitudinal length of the drift. Each complete size range zone would be roughly the length of a backfill pipe segment with the segregation again repeating the next 6 m, and so on. This segregation may not be as pronounced in areas where a waste package is located because material striking and bouncing off the outer surface of the package may cause better mixing to occur.

A method of addressing the particle size segregation described above would be to provide a 6 m long telescoping section of pipe to allow the backfill pipe to be moved in and out of the drift for each length of the conveying pipe. This method could provide better mixing of different particle sizes. The telescoping section of pipe would consist of an inner pipe with an outer, larger diameter pipe sleeve. The upstream end of the sleeve pipe would be constructed with an air seal ring(s) to prevent air pressure leakage from the pipe line. The front or downstream end of the outer pipe sleeve would be constructed with a reducer to change the diameter back to the main conveying pipe size. Each end of the telescoping section would be equipped with whatever style pipe coupling or flange used for the remainder of the conveying pipe line.

To provide placement of the upper sand layer, the lower coarse material would be placed first for the entire length of the drift. The backfill conveying pipe would then be pushed back into the drift from both the TBM launch main and perimeter mains. Both pipe line lengths would then be 600 m ± long. Sand would be placed on top of the coarse material layer by again retreating each pipe line out of the drift.

Several key considerations should be emphasized regarding backfill placement quality:

- Although mixing of the coarse material can be accomplished as described above, it will be difficult to predict what the in-place gradation and compaction of this material will be. The effect of the waste packages in the backfill stream will further increase prediction difficulty.

- The top of coarse material could be uneven depending on how the pipe line was moved during the backfilling operation. A possible way to "grade" the coarse material to an approximate (but likely not exact) sloping configuration described in Section 9.1.1.1 would be to move a traveling, vibrating screed down the length of the drift. The screed could be designed to travel on the backfill pipe support monorail beam.

- Careful metering of material volume would be required to predict how the operation was proceeding and to ensure a relatively constant coarse material height down the length of the drift.

- The top layer of sand (or top of the coarse material if sand was not used) could never be placed any higher than roughly the bottom of the backfill pipe, unless a flexible, remote-controlled nozzle could be designed to aim the backfill stream at the drift roof. This flexible elbow would represent a significant wear item in the system.

10. COST ESTIMATING

As of the time of this report, no definitive cost estimate has been developed for repository design. This work is scheduled to be accomplished in FY 1995 and FY 1996.

11. SCHEDULE AND MILESTONES

The ACD phase precedes future design and construction efforts as depicted in Figure 11-1. This figure also illustrates the integration of design among various repository elements that include design, construction, license application, permitting, and data needs. Following is a description of key milestones as they are developed for the OCRWM Proposed Program Approach to overall project scheduling.

11.1 KEY MILESTONES

11.1.1 Project Summary Milestones

The milestones were developed under the program plan known as the Proposed Program Approach (PPA). Under this plan, the Technical Site Suitability (TSS) in late FY 1998 is expected to cover DOE's evaluation of site suitability with respect to all the qualifying and disqualifying conditions of 10 CFR 960, except for those pertaining to environmental, socio-economic and transportation. The latter conditions will be addressed through the NEPA process.

The Draft EIS (DEIS) in late FY 1998 will be prepared in accordance with the requirements of NEPA (as modified by the NWPA) and implementing regulations. It is expected to address environmental impacts associated with repository construction, operations, postclosure, and transportation.

The Final EIS (FEIS) in late FY 2000 will address comments received from the public on the DEIS and include any relevant additional information that has become available since the time the DEIS was issued. The FEIS will accompany the recommendation to the President, if the site is suitable.

The Site Recommendation Report (SRR) in late FY 2000 will be submitted to the President if the site is found suitable. It will be prepared in accordance with the content requirements of Section 114 of the NWPA.

The License Application (LA) will be submitted to the NRC in mid to late FY 2001, if both the President and Congress approve the site recommendation. The LA will be prepared in accordance with the content requirements of 10 CFR 60.21 and the NRC's Format and Content Regulatory Guide. The LA will be used as the basis for NRC issuance of the Construction Authorization.

It is expected that the NRC will issue the Construction Authorization (CA) in late FY 2004, after it has reviewed the LA and conducted the required hearings. This will be the point in the licensing process when the NRC makes its "reasonable assurance" finding in accordance with 10 CFR 60, which will be based on the information DOE provides in the LA and any subsequent supplements. Upon receipt of the CA, construction of the repository may begin.

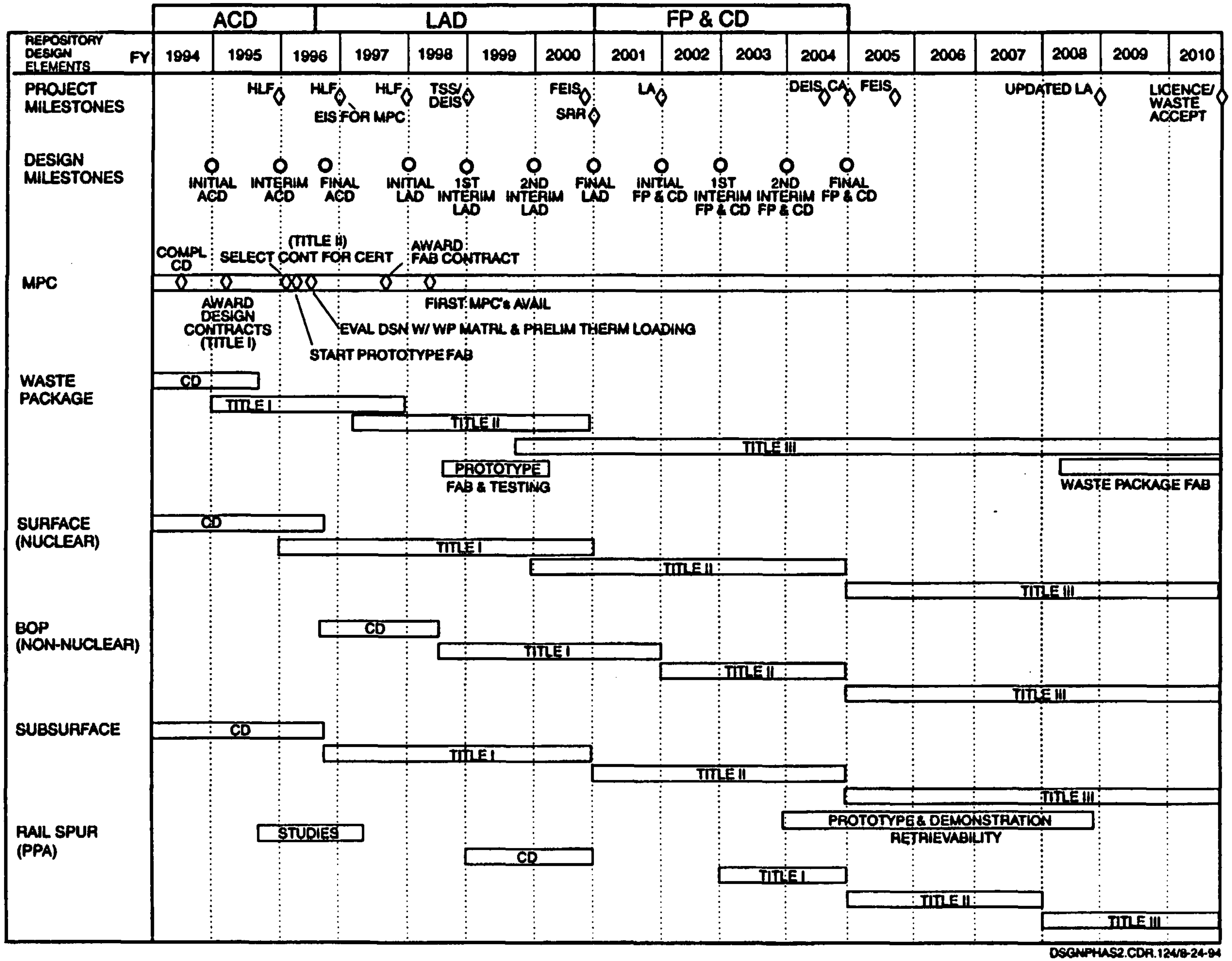


Figure 11-1. Design Phases

The updated LA would be submitted to the NRC in late FY 2008, after sufficient construction (both surface and subsurface) has been completed to support initial operations. This updated LA will be the basis for NRC issuance of the license to receive and possess waste.

NRC issuance of the license to receive and possess waste is expected in late FY 2010, after it has reviewed the updated LA and conducted any required hearings. At this point, DOE may start accepting waste at the repository.

11.2 SITE SUITABILITY

11.2.1 Site Suitability Process

The higher level findings (HLFs) required for site suitability by 10 CFR 960 are expected to be conducted in a step-wise manner. Generally, the process would entail the preparation of a technical report that combines different qualifying and disqualifying conditions that are similar in topical area; this report would be peer reviewed. DOE would then make the regulatory assessment needed for the higher level finding. Indicated below are the key milestones related to the HLFs.

HLFs in FY 1995 will address the topic of surface processes and will include erosion, surface characteristics, and preclosure hydrology.

HLFs in FY 1996 will address the topics of preclosure rock characteristics and preclosure radiological safety. The latter topic, radiological safety, also includes site ownership and control, population density, off-site installations, and meteorology.

HLFs in FY 1997 will address the topics of tectonics and reasonably available technology. The former topic includes the postclosure tectonics disqualifying condition and the preclosure tectonics qualifying and disqualifying conditions.

HLFs in FY 1998 will address the topics of pre-waste-emplacement groundwater travel time, the postclosure system guideline, and all the remaining postclosure qualifying conditions - geohydrology, geochemistry, rock characteristics, climate, and tectonics. Also, a report on Technical Site Suitability will be issued consolidating these HLFs and all previous ones into a single document.

In late FY 2000, the SRR will be issued to the President combining the results of the TSS and the NEPA process, in addition to the other items called for in Section 114 of the NWPA.

11.3 NEPA

11.3.1 Repository

In mid-FY 1995, a Notice of Intent will be issued in the Federal Register to announce DOE's intent to prepare an EIS for the repository and initiate the public scoping process required by NEPA.

In late FY 1998, DOE will issue a DEIS for public comment (see "Key Milestones" above).

In late FY 2000 DOE will issue an FEIS (see "Key Milestones" above). No sooner than 30 days later, DOE will issue a Record of Decision (ROD), as required by NEPA,which will document DOE's decision to proceed with this major Federal action.

In late FY 2008, it is expected that DOE would prepare an EIS Supplement to address additional information regarding potential environmental impacts that have become available since the issuance of the original FEIS. This supplement would accompany DOE's updated LA to be submitted to the NRC for receipt of the license to receive and possess waste.

11.3.2 Nevada Rail Spur

This NEPA process applies only to the construction of the Nevada rail spur. The timing of this process is such that the spur would be available for use by the time DOE obtains the license to receive and possess waste (projected year 2010).

In late FY 2002, a Notice of Intent will be issued in the Federal Register to announce DOE's intent to prepare an EIS for the rail spur construction and initiate the public scoping process required by NEPA.

In late FY 2004, DOE will issue a DEIS for public comment. The DEIS will be prepared in accordance with the requirements of NEPA (as modified by the NWPA), and implementing regulations. It is expected to address environmental impacts associated with construction of the rail spur within Nevada.

In late FY 2005 DOE will issue an FEIS. The FEIS will address comments received from the public on the DEIS and include any relevant additional information that has become available since the time the DEIS was issued. No sooner than 30 days later, DOE will issue a Record of Decision (ROD), as required by NEPA, which will document DOE's decision to proceed with this major Federal action.

11.4 LICENSING

11.4.1 Issue Resolution

Pre-licensing issue resolution and interaction activities will continue to be conducted until the LA is submitted to the NRC in FY 2001. The issues being actively addressed at this time include: extreme erosion, origin of calcite-silica deposits, seismic hazards, volcanism, substantially complete containment, boundary of the engineered barrier system, pre-waste-emplacement groundwater travel time, and burnup credit. As other issues are identified, they will be addressed and documentation prepared to support resolution with the NRC.

After the LA is submitted in FY 2001, the DOE and NRC enter into a formal process for resolving issues and interacting. This includes the NRC review of the LA, NRC issuance of a Safety Evaluation Report, and the hearings that are conducted in accordance with 10 CFR 2. After the CA is issued by NRC and DOE begins construction, NRC will continue to interact with DOE in a formal manner as the regulator.

11.4.2 LA Annotated Outline

Revision 4 (early FY 1995): The scope of the MGDS License Application Annotated Outline (LA AO) Revision 4 includes the following:

- Complete Chapter 3 [assuming section 3.1 is completed by incorporating the updated Site Description (funded out of WBS 1.2.3].

- Update Chapter 6 to incorporate the results of TSPA 1993.

- Resolve NRC comments on LA AO Revisions 2 and 3.

- Track acquisition of information needed in licensing by developing and implementing regulatory databases and coordinating with PACS.

- Produce Site Characterization Program Feedback Report from Revision 4 information needs and input into annual planning and long range planning process.

Revision 5 (early FY 1996): Fully implement the LA AO process to initiate the repository program licensing approach outlined in the Regulatory Compliance Plan. The process involves the following:

- Integrate multi-disciplinary technical expertise into a unified repository licensing approach by writing skeleton text using NRC guidance. Reference all existing information and specifically identify the need for missing information.

- Import applicable sections of the SCP into the appropriate LA AO sections and document the linkage for inclusion in the transition matrix in RCP Appendix A.

- Specifically identify the missing information needed to support the unified licensing strategy and define data/designs/analyses needed from the site characterization, design, and performance assessment programs.

- Link LA AO information needs to the Project plans that are currently in place to acquire such information. In this manner, the LA AO process either verifies the site characterization program or initiates a request to change it.

- Produce Site Characterization Program Feedback Report from LA AO information needs and input into annual and long range planning process. In effect, produce specifications for data, designs, and analyses deliverables from Site Characterization activities.

Revision 6 (early FY 1997): Evaluate information from site characterization for use in licensing and incorporate/update LA AO sections, as appropriate. A request to initiate changes to the project plans may be necessary as a result of LA AO development. Similarly, a request may be initiated to defer or eliminate studies that are no longer needed in support of licensing. The dynamic feedback provided by this phase of the process focuses site characterization activities on the acquisition of information needed to support the unified licensing approach embodied in the LA AO.

Revision 7 (early FY 1998): Evaluate information from site characterization for use in licensing and incorporate/update LA AO sections, as appropriate. A request to initiate changes to the project plans may be necessary as a result of LA AO development. Similarly, a request may be initiated to defer or eliminate studies that are no longer needed in support of licensing. The dynamic feedback provided by this phase of the process focuses site characterization activities on the acquisition of information needed to support the unified licensing approach embodied in the LA AO.

Revision 8 (early FY 1999): Evaluate information from site characterization for use in licensing and incorporate/update LA AO sections, as appropriate. A request to initiate changes to the project plans may be necessary as a result of LA AO development. Similarly, a request may be initiated to defer or eliminate studies that are no longer needed in support of licensing. The dynamic feedback provided by this phase of the process focuses site characterization activities on the acquisition of information needed to support the unified licensing approach embodied in the LA AO.

Revision 9 (early FY 2000): Finalize LA AO for use in DOE's request for preliminary comments from the NRC related to the extent to which at-depth site characterization analysis and the waste form proposal seem to be sufficient for inclusion in any LA. These comments must be included in the Site Recommendation Report (SRR) pursuant to NWPA Section

114(a)(1). After Revision 9 is issued, the LA AO will be converted into a draft license application by incorporating information that satisfies all remaining information needs and initiating formal license application review.

LA (mid-FY 2001): Incorporate Congressional Resolution of Site Approval into the LA and forward to the Secretary of Energy. The Secretary of Energy submits the Mined Geologic Disposal System (MGDS) LA to the NRC. This must occur no later than 90 days after Congress passes a joint resolution of siting approval, as required in NWPA 114 (b). The LA must contain the general information and the Safety Analysis Report (SAR) specified in 10 CFR 60.21. The LA must also be accompanied by the EIS.

CA, Updated LA, and License: See above under "Key Milestones."

11.5 PERFORMANCE ASSESSMENT

11.5.1 Total System PA

Each PA iteration should include total system and applicable sub-system analyses. Each PA iteration should include ample sensitivity/uncertainty analyses to indicate the significance of assumptions. Each PA iteration is assumed to take a full year of analyses. The analysis portion is assumed to be preceded by a six month planning phase. The analysis portion is assumed to be followed by a period to prepare the summary document describing the major findings and remaining uncertainties. Following the summary document, an additional three months are allowed for external and internal review. Thus, the time between full TSPA iterations is about two years.

The next PA iteration, TSPA-1995 (in late FY 1995), is to be a dry run for the TSPA that is to feed the TSS. The reason a dry run is needed is that TSPA-1991 and -1993 were "conservative" analyses that assumed bounds on data that led to the system not meeting certain performance measures in current applicable and non-applicable regulations. A trial TSPA that represents site data ranges less conservatively is needed relatively soon, to allow at least a year for specific additional data gathering and code enhancement activities to be conducted prior to TSPA-1997. TSPA-1995 is somewhere between the "Conservative" and "Bounded" classifications, in that it attempts to insert more realism, but data sparsity demands that conservative estimates still be used in key data distribution assumptions.

TSPA-1997 (in late FY 1997) and related PA calculations will directly feed the TSS by supporting HLFs on the postclosure system performance guideline [10 CFR 960.4-1(a)] and the qualifying conditions requiring assessment of postclosure performance (i.e., Geohydrology, Geochemistry, Rock Characteristics, Climate, and Tectonics). This is a "Bounded" calculation in that there are sufficient data and information to come closer to a realistic and defensible calculation than in previous TSPAs.

TSPA-1999 (in late FY 1999) and related PA calculations will directly feed the FEIS and SRR. This is also a "Bounded" calculation, and an improvement over the previous iteration in terms of the data and information allowing a realistic and defensible calculation.

TSPA-2001 (in early FY 2001) and related PA calculations will directly feed the LA for the CA. However, this PA iteration will be somewhat abbreviated and only the key issues identified following the TSPA-1999 iteration will be addressed; hence its labeling as TSPA Revisions. The label "Subfinal" may be applied to this iteration, since the LA contains calculations that must satisfy the criterion of a reasonable expectation that results will not be changed by new data from the Performance Confirmation program.

11.5.2 Waste Package Subsystem PA

The PA activities addressed here are those addressing the Substantially Complete Containment subsystem performance requirement of 10 CFR Part 60. It is to be noted that future TSPA iterations are to progressively begin to address the system-level regulatory criteria more fully, including preclosure and postclosure, total system, and sub-system criteria. In this context, estimates of subsystem behavior will be part of each TSPA iteration.

Bounded (mid-FY 1997): This is to be used as part of the Waste Package Title I design documentation that is to be prepared by FY 1998. This analysis is to be "realistic and defensible" as per the "Bounding" definition. This is the limit to which available design and testing data can be interpreted by 1997.

Final (late FY 2000): This is the WP subsystem PA that is part of the documentation for the Waste Package Title II design, scheduled to be completed by 2001. This analysis is "Final" in that it supports compliance with the Substantially Complete Containment requirement, and further testing is not expected to change the analytical conclusions. In order to make this a "Final" subsystem model, the design must be sufficiently robust to allow for the fact that certain testing activities are not as complete at 2001 as had been previously planned: (1) Waste package material testing will be less than 100 percent of what was previously planned to support the LA at 2001, and (2) Near Field Environment studies will be less than 50 percent of what was previously assumed necessary for 2001.

11.5.3 Groundwater Travel Time Subsystem PA

The PA activities addressed here address the Groundwater Travel Time site subsystem performance requirement of 10 CFR Part 60. It is to be noted that future TSPA iterations are to progressively begin to address the system-level regulatory criteria more fully, including preclosure and postclosure, total system, and subsystem criteria. In this context, estimates of subsystem behavior will be part of each TSPA iteration.

Bounded (mid-FY 1997): This is to serve as an in-depth treatment of this issue, and is intended to be a "realistic and defensible" estimate of this performance measure as defined in

10 CFR Part 960. This in-depth treatment is to a large extent dependent on progress in the site-scale models being provided by the Site Investigations function, which, since they are to be at the "Bounded" state of development, largely dictate the limit to which the technical status of the GWTT calculation can be interpreted by 1997.

Subfinal (late FY 2000): This GWTT subsystem PA is to support the SRR and the LA. At this point in time, the site-scale models will have advanced beyond the "Bounded" state of development. The logic for expecting the GWTT calculation to be at the "Subfinal" state here lies in the expectation that the changes in the site-scale models resulting from new information will not cause substantive changes to the conceptual understanding of water flow in the unsaturated environment of Yucca Mountain, and that the database supporting the radionuclide transport part of the GWTT calculations addressing 10 CFR Part 960 will also be relatively mature at this point in time.

Final (late FY 2007): This GWTT subsystem PA is to support the 2008 Updated LA. At this point in time the supporting site-scale models are largely in the "Subfinal" state of development. Continued confirmatory testing is to result in the finalization of those models, which will be important to updating TSPAs, but no further changes in estimates are expected from further developments in data and information.

11.5.4 Engineered Barrier System (EBS) Subsystem PA

The PA activities addressed here address the Controlled Release Rate subsystem performance requirement of 10 CFR Part 60. It is to be noted that future TSPA iterations are to progressively begin to address the system-level regulatory criteria more fully, including preclosure and postclosure, total system, and sub-system criteria. In this context, estimates of subsystem behavior will be part of each TSPA iteration.

Conservative (mid-FY 1997): This EBS subsystem PA is to be used as part of the evolving repository design. This analysis is to be based on an Areal Power Density that is not yet final, and a repository design that is in the initial stages of Title I. At this point in time, significant design decisions are not yet final, and available design and testing data are less mature for determining releases from failed containers than they will be for supporting estimates of the time of failure for those containers.

Bounded (late FY 2000): This EBS subsystem PA is to be part of the repository Title I design documentation scheduled to be completed by late FY 2000. This analysis is "Bounded" in that it supports the finding that performance estimates for the Controlled Release Rate criterion are "realistic and defensible" based on the results of design and testing. The "Bounded" classification in this instance should actually be somewhere between "Conservative" and "Bounding," because testing related to the Near Field Environment at 2001 will be about 50 percent, and testing of waste form release will be about 25 percent of what was previously considered necessary to support the LA.

Final (late FY 2007): This EBS subsystem PA will be produced in support of the 2008 Updated LA. To make this a "Final" analysis, the repository Title II design basis is available for the calculations, and testing related to the Near Field Environment and to waste form release behavior in that environment must be substantially complete. Confirmatory testing in both these areas will continue after waste begins to be emplaced, however.

11.6 SITE INVESTIGATIONS

11.6.1 Three-dimensional Geologic Description

Subfinal (early FY 1997): The major objectives of SCP Studies 8.3.1.4.2.1, 8.3.1.4.2.2, and 8.3.1.4.2.3 will have been achieved, leading to an essentially complete geologic framework model for the site. The geologic framework model will include the definition and description of all appropriate stratigraphic units within the Tertiary volcanic section at the site and the location and description of the major structural features at the site. Additional site information would be used to refine the model but would not be expected to require substantive changes to the model. This Subfinal degree of completeness is needed as a basis for site hydrologic and performance-assessment modeling to support the technical site suitability evaluation and the license application.

Final (early FY 2000): This includes all activities under SCP Studies 8.3.1.4.2.1, 8.3.1.4.2.2, and 8.3.1.4.2.3 with respect to available site data and information. No additional activities would be planned specifically to support further development of the site geologic framework model. Additional site data would be used to refine the model but would not be expected to require major changes to the model. A final status is needed because of the fundamental importance of the geologic framework for siting and evaluating the performance of the geologic repository.

Updated (late FY 2007): Additional site geologic data that would become available would be ancillary to other studies and would be incorporated into the site geologic framework model. These data would be expected to permit refinement of model details or, perhaps, to permit extension of the lateral and vertical domain of the model but would not be expected to lead to substantive changes within the existing model domain.

11.6.2 Climate Description

Conservative (early FY 1997): Based on evaluations of modern climatic conditions and conditions occurring during the Quaternary Period, as inferred from paleoclimate and paleoenvironmental studies, the timing, duration, and magnitude of possible *extreme* future climatic change would be estimated. The magnitude of climatic change would be estimated quantitatively as the effective moisture (precipitation minus evapotranspiration), which is the quantity most relevant to possible climatic induced changes in the site and regional hydrologic systems. 10 CFR 960 specifically requires that consideration of climatic conditions in the Quaternary be the basis for evaluating future climatic change.

Bounded (early FY 2000): Sufficient data from the paleoclimate program and preliminary future-climate modeling studies would be needed to set realistic bounds on the timing, duration, and magnitude of expected future climatic change. In addition, bounding relations for translating effective moisture into net infiltration and recharge need to be developed to support site and regional hydrologic modeling and performance-assessment modeling.

Subfinal (late FY 2007): The major objectives of the paleoclimate and future-climate programs as described in the SCP need to be achieved in order that performance assessment can adequately address the expected effects of future climatic change on waste containment and isolation. Additional data and climate-modeling would permit refinements of model details, but would not be expected to lead to substantive changes in the evaluation of possible consequences of expected future climatic change.

11.6.3 Postclosure Tectonics Description

Bounded (early FY 1997): Based on data from volcanism and faulting studies in the region and near the site, limits on the likelihood of occurrence of igneous activity or faulting that could disrupt the postclosure repository would be estimated. Because these likelihoods are expected to be small for the site, bounding values based on partial information will suffice for the technical site-suitability evaluation.

Bounded (early FY 2000): Additional site and regional data will permit updating and refinement of the limiting likelihoods used for the technical site-suitability evaluation and would be sufficient to support the license application.

Subfinal (late FY 2007): The major objectives of the SCP tectonics program need to be achieved at this point to support detailed performance-assessment evaluations of the consequences for waste containment and isolation due to possible future tectonic processes at the site.

11.6.4 Unsaturated/Saturated Geochemistry Description

Bounded (early FY 1997): Realistic limits on the mineralogic composition, water chemistry, and geochemical retardation properties of the site are needed at or between key horizons (such as, most importantly, the Calico Hills non-welded hydrogeologic unit between the potential repository and the water table) and for selected representative radionuclides to support the technical site-suitability evaluation.

Bounded (early FY 2000): Additional data will be needed to refine and extend the limits to additional units and radionuclides other than those used for the technical site-suitability evaluation in order to support a demonstration of substantially complete containment and subsequent performance-assessment evaluations.

Subfinal (late FY 2007): The major objectives of the SCP geochemistry program will need to be achieved in order to support realistic performance-assessment evaluations for the repository system. Additional data would enlarge the geochemical database but would not be expected to change major results and conclusions.

11.6.5 Unsaturated Zone (UZ) Hydrologic Description

Bounded (early FY 1997): Bounding limits on expected ground-water fluxes in the unsaturated zone are needed to support performance assessment. Based on geohydrologic and geochemical evidence (e.g., fracture mineralogy and chlorine-36 data), bounds on the presence of present and past active preferential flow pathways in the unsaturated zone need to be established. Bounds on the occurrence and factors controlling the occurrence of perched water also need to be established. Finally, limiting conditions on sustained non-equilibrium flow in fractures and faults and rates of imbibition into the adjacent rock matrix need to be established. Sufficient data are needed to support ground-water travel-time evaluations in the context of the disqualifying condition in 10 CFR 960 for the site-suitability evaluation.

Bounded (early FY 2000): Improved bounds on expected ground-water flux at the repository horizon will be needed to support a demonstration of substantially complete containment.

Subfinal (late FY 2007): The major objectives of the unsaturated-zone geohydrology program will need to be achieved in order to provide percolation-flux fields needed to support performance-assessment evaluations.

11.6.6 Saturated Zone Hydrologic Description

Bounded (early FY 1997): Bounds on ground-water flow velocities, mixing depth, and existence of preferential flow pathways in the saturated zone need to be estimated and will be adequate for performance-assessment evaluations to support the technical site-suitability evaluation.

Bounded (early FY 2000): The limits established for the technical site-suitability evaluation will be refined for input to performance-assessment models to support the application for construction authorization.

Subfinal (late FY 2007): The major objectives of the saturated-zone geohydrology program will need to be achieved in order to provide ground-water flow-field data to support performance-assessment modeling.

11.6.7 Thermal Effects Description

Bounded (early FY 1997): Bounding estimates of the maximum magnitude and spatial extent of repository induced temperature change will suffice for evaluating technical site suitability and supporting EIS preparation.

Subfinal (early FY 2000): Reasonably accurate and complete knowledge of expected repository-induced thermal effects, especially the early near-field thermal environment, will be needed to demonstrate substantially complete containment.

Final (late FY 2007): Essentially complete and final knowledge of the repository-induced thermal regime will be needed to support performance-assessment evaluations.

11.7 ESF CONSTRUCTION

11.7.1 ESF 7.8 Kilometer Loop

Complete Accesses to Ghost Dance Fault (late FY 1996): Complete TBM excavation at the Topopah Spring level to approximately Station 52 + 00m, including Ghost Dance Fault penetrations necessary to identify the potential existence of water, the North Ramp extension with a 5.5 m diameter TBM, and thermal test area penetrations at the North Ramp extension.

Complete 7800 m Loop (mid-FY 1997): Complete TBM excavation at the Topopah Spring level to the South Portal. Completion of this milestone may be delayed if excavation to the Calico Hills level is required based on information gathered from the Ghost Dance Fault penetrations.

11.7.2 Calico Hills

Evaluate Options Calico Hills (CH) Access (Slant Drilling/Excavation) (late FY 1995): Evaluate options and select method for access to the Calico Hills level based on the potential discovery of water at the Ghost Dance Fault penetrations at the Topopah Spring level. Develop the design(s) necessary to implement the selected Calico Hills access.

Implement CH Decision (late FY 1996): Implement the selected design and excavation option for the Calico Hills access assuming that information from the Ghost Dance Fault penetrations at the Topopah Spring level requires investigation at the Calico Hills level.

11.8 REPOSITORY/WASTE PACKAGE

11.8.1 Repository

Complete Advanced Conceptual Design (ACD) (end of FY 1996): The goal of the ACD phase is to develop the repository design to a conceptual level of detail that will confirm the technical feasibility of the proposed operations, satisfy statutory requirements, allow the preparation of reliable total system life cycle costs and performance schedules, and identify environmental safety features. The ACD will provide the basis for the DEIS. Major design products include basic facility and component drawings that show significant features and general arrangements, an energy conservation report, project design criteria that include health, safety, safeguards and security requirements, and identification of design uncertainties and contingencies. The final ACD Report is required to support the DOE Key Decision 1 (KD1) milestone.

Complete Title I Design (late FY 2000): Title I Design is also referred to as Preliminary Design. The goal of the Title I Design phase is to utilize the Advanced Conceptual Design to firmly establish (freeze) the repository concept of operations and major design features, further refine the repository costs and performance schedules, complete evaluations of key design alternatives, and provide additional design input to the FEIS. Major Title I Design products include preliminary drawings that expand on the conceptual level of detail and reflect the finalized concept of operations and the recommendations from the evaluations of alternatives. Outline specifications for equipment procurement and construction are prepared. The preliminary drawings and outline specifications are used to develop more accurate cost estimates and performance schedules. Preliminary estimates of construction labor, equipment and material quantities, and long-lead procurement items are developed. Design features that assure compliance with health, safety and environmental regulations are further developed and analyzed. A Preliminary Safety Analysis Report (required by DOE Orders) is also prepared during the Title I Design phase. The Title I Design Report is required to support the DOE Key Decision 2 (KD2) milestone and submittal of the NRC License Application for a repository.

Complete Title II Design (late FY 2004): Title II Design is also referred to as Definitive Design. The goal of the Title II Design phase is to utilize the Title I Design to develop detailed construction drawings, equipment lists, detailed procurement and construction specifications, detailed construction cost estimates, and firm construction and start-up schedules. Major Title II Design products include various construction packages that contain approved for construction (AFC) drawings, detailed procurement and performance specifications, firm construction schedules, testing and operational start-up plans, equipment procurement plans, and detailed estimates of construction labor, equipment and material quantities. A Final Safety Analysis Report (required by DOE Orders) is also prepared during Title II Design phase. The Title II Design Report is require to support the DOE Key Decision 3 (KD3) milestone.

Complete Construction (Title III Design) (late FY 2010): After the CA is received from NRC, repository construction will commence. Title III Design assures through ongoing inspection activities that the construction is proceeding in accordance with the approved drawings, specifications and plans. Inspection services include verification of vendor drawings and equipment, construction workmanship, materials and equipment. Approved changes to the Title II Design packages will require preparation of as-built drawings and revisions to specifications. Completion of Title III Design (construction) is required to support the DOE Key Decision 4 (KD4) milestone. This milestone is complete when sufficient construction (both surface and subsurface) has been done to support initial repository operations.

11.8.2 Waste Package

Complete Advanced Conceptual Design (ACD) (late FY 1995): The goal of the ACD phase is to develop the Waste Package/Engineered Barrier System (WP/EBS) design to a conceptual level of detail that will confirm the technical feasibility of the proposed operations, satisfy statutory requirements, allow the preparation of reliable total system life cycle costs and performance schedules, and identify environmental safety features. Major design products include WP/EBS design concepts, MPC, Uncanistered, and Defense High Level Waste (DHLW), waste package handling, closure processes, NDE/ISI processes, component drawings, assembly drawings, preliminary specifications, and general arrangements, project design criteria, and identification of design uncertainties and contingencies. The final ACD Report is required to support the DOE Key Decision 1 milestone. The ACD will provide the basis for the DEIS.

Complete Title I Design (late FY 1997): Title I Design is also referred to as Preliminary Design. The goal of the Title I Design phase is to utilize the Advanced Conceptual Design to firmly define the leading WP/EBS concepts and the concept of operations and major design features, further refine the associated WP/EBS costs and performance schedules, complete evaluations of key design alternatives, and provide additional design input to the FEIS. Major Title I Design products include preliminary drawings that expand on the conceptual level of detail and reflect the finalized concept of operations and the recommendations from the evaluations of alternatives. Outline material, component, and assembly specifications for procurement and fabrication are prepared. The preliminary drawings and outline specifications are used to develop more accurate cost estimates and performance schedules. Preliminary estimates of fabrication labor, equipment and material quantities, and long-lead procurement items are developed. Design features that assure compliance with long term containment of the waste are further evaluated and analyzed, including probabilistic evaluation of the WP/EBS system. A Preliminary Safety Analysis Report (required by DOE Orders) is supported during the Title I Design phase. The Title I Design Report is required to support the DOE Key Decision 2 milestone.

Complete Title II Design (late FY 2000): Title II Design is also referred to as Definitive Design. The goal of the Title II Design phase is to utilize the Title I Design to develop detailed WP/EBS design and fabrication drawings, equipment lists, detailed procurement and material and component/assembly engineering and fabrication specifications, detailed fabrication and assembly cost estimates, and fabrication and construction and start-up schedules. Major Title II Design products include various design and fabrication packages that contain approved for construction (AFC) drawings, detailed procurement and long term performance specifications, firm fabrication and construction schedules, testing and handling, closure, NDE/ISI, WP filler operational start-up plans, equipment procurement plans, and detailed estimates of construction labor, equipment and material quantities. A Final Safety Analysis Report (required by DOE Orders) is also prepared during the Title II Design phase. The Title II Design Report is require to support the DOE Key Decision 3 (KD3) milestone and will form the basis for the LA.

Complete Prototype (Title III Design) (late FY 2004): This phase will focus on NRC licensing issues raised during the review of the LA, WP processing through the surface and subsurface facilities, performance confirmation test planning/testing, and material, component specification, and drawing package (Waste Package Parts List). Inspection services include verification of vendor drawings and equipment, fabrication and construction workmanship, materials and equipment. Approved changes to the Title II Design packages will require preparation of as-built drawings and revisions to specifications. Completion of Title III Design (Prototype) is required to support the DOE Key Decision 4 (KD4) milestone.

Complete Fabrication (late FY 2010): By this period in time, fabrication of the waste packages needed to support initial waste emplacement is completed.

11.9 RAIL SPUR

11.9.1 Rail Spur

Route Analysis/Conceptual Design (late FY 2000): An evaluation of the Nevada rail spurs pre-conceptual studies and one completed conceptual study to date will be performed and routes will be selected for conceptual design. Conceptual design may be performed on more than one route. The design package will include a conceptual level cost estimate for performing further design, construction, and operation of the rail spur. This information will be used for the repository DEIS.

Title I Design (mid-FY 2004): A Title I design will be performed on the Nevada rail spur route selected. At the end of the Title I design, the design will be essentially "frozen" with no major changes expected in later stages of design. A design package including report, drawings, cost estimate, and outline specifications will be prepared for the rail spur facilities to meet DOE Order 4700.1 and other requirements.

Title II Design (late FY 2007): Title II design will be performed on a single route base on the design developed during Title I. Detailed construction and procurement drawings and specifications will be developed. A detailed cost estimate for Title III engineering, construction, and operations will also be produced at the end of Title II.

Rail Spur Construction (late FY 2010): Construction of the Nevada rail spur will be done in time to support accepting waste in the repository by 2010.

12. UNCERTAINTIES, ISSUES, AND RECOMMENDATIONS

With the current dearth of underground data, the levels of uncertainty are high for a number of parameters that may be important to waste isolation. If these uncertainties could be reduced, the understanding of waste isolation/waste emplacement would be improved. Sensitivity analyses are needed to fully identify parameters important to waste isolation. Based on this, it will be necessary to ensure that test programs can provide the necessary data to reduce uncertainties. Some studies have been done, including the FY 1993 Thermal Loading Study (M&O 1994u), which have identified some of these uncertainties. A synopsis of the parameters or issues identified where uncertainty currently exists is provided below for those parameters influenced by thermal loading. The issues are divided into five areas: Waste Stream, Waste Package, Geochemistry, Hydrothermal, and Cost.

12.1 WASTE STREAM

In the area of uncertainties about waste and waste characteristics, the issue that must be addressed is the effect fuel variability has on thermal loading. The variability could produce local hot or cold spots which could influence pre- and postclosure performance. This issue will be evaluated in the FY 1994 Thermal Loading Study.

12.2 WASTE PACKAGE

Certain issues must be considered in establishing the performance of Waste Packages (WPs). Specifically, the corrosion of the WP materials under conditions in the potential repository over long time periods is not well known, and estimates differing by an order of magnitude are currently used. Thus, it will be necessary to establish corrosion initiation time and rates as a function of temperature, humidity, and time (for corrosion rates).

There is considerable uncertainty as to what performance allocation can or should be given for the fuel cladding. It is possible that no postclosure performance can be obtained from the cladding. In any case, it will be necessary to ensure that the cladding has sufficient mechanical integrity for retrieval operations. This is particularly important given the use of large WPs to accommodate large multi-purpose canisters (MPCs). The time/temperature dependence of fuel cladding performance needs to be investigated.

12.3 GEOCHEMISTRY

The effect of geochemical changes, due to thermal and liquid saturation changes, on radionuclide and bulk hydraulic conductivity is not well understood. To obtain a better understanding of these processes, it is suggested that certain additional information is needed. Data on energetics of zeolite dehydration and transformation (recrystallization) are of specific interest. There is significant variation in the stratigraphy with respect to concentrations of the zeolite-bearing moderately and nonwelded tuffs, clays, and volcanic glasses. Thus, information is required on the effects of existing lateral stratigraphic variations, in particularthe differences between sections where CHn is thickest (west) and thinnest (east).

Finally, mineralogic alteration on rock properties in terms of how or to what degree heterogeneities might be introduced needs to be understood.

A significant uncertainty in the geochemistry area is the changing water chemistry occurring as a result of the thermal environment; also, the impact of changes in water chemistry on the Engineered Barrier System (EBS) (particularly WP corrosion), fuel alteration, and radionuclide dissolution. This information is needed for understanding the implications of above-boiling conditions.

Another significant uncertainty at this time is how much actual usable area exists at the repository horizon. Determination of this issue must wait until additional drilling is completed and the ESF is actually excavated. Even this may provide only a partial answer on a relatively small area, but the results should be possible to correlate with borehole information.

12.4 HYDROTHERMAL

Better information is required on the host rock matrix properties and fracture densities in the potential repository. Bulk permeability, both gas and liquid, is uncertain and variations in this parameter can significantly influence the transport of both heat and fluid. The uncertainty in this parameter must be reduced as well as a determination of the degree of heterogeneity that exists in the potential repository. As a part of this, the fracture-matrix interaction in the unsaturated zone must be better known. This information will not only affect the postclosure performance but also will impact the WP and drift-scale hydrothermal regimes.

Numerical simulations have predicted formation of dry-out for sufficiently high heat loads. However, these predictions are an average over a fairly extensive area and assume local thermodynamic equilibrium between rock and fracture matrices (Pruess and Wang, 1987, and Pruess and Tsang, 1993). It has not been established whether thermodynamic equilibrium in fact holds on a drift or WP scale. The potential repository host rock is known to be heterogeneous to some degree. As such, one may expect differential drying and condensation effects that could minimize fluid flow near some packages while enhancing it near others. This needs to be investigated further.

An important example of these uncertainties is the bulk permeability. Prediction of water movement has been shown, in Section 5 and Appendix F, of the Thermal Loading Study (M&O 1994u) to be sensitive to bulk permeabilties. A value of 280 milliDarcys is representative of rock that has three 100 micron fractures per meter. However, recent analysis (SNL 1993c, 1993d) has shown that the linear fracture frequency needs to be corrected by the angle the fracture makes with the borehole. When this is done, the fracture density in the Topopah Spring Unit is estimated at about 15 fractures per meter. Although this is significantly higher than the figures used in the thermal loading study, no fracture size information was available in the report to estimate bulk permeability. The report documented limited checking of the calculation with the conclusion that they appeared valid, but it warnedthat the derived correction factor may overestimate the number of vertical fractures. Clearly this uncertainty as to actual bulk permeability must be resolved in order to accurately predict fluid movement in the mountain.

Another significant uncertainty is the percolation flux that exists in the mountain. The TSPA study (M&O, 1993k) showed that under some conditions, an increased percolation flux will produce a significant increase in the release of radionuclides to the accessible environment. An example of this is shown in Figure 12.1 in which the normalized total release of Tc99 to the accessible environment is plotted as a function of liquid flux in terms of a parameter QFLUX for a 10 cm thick WP emplaced at 57 kW/acre.

Thermo-mechanical calculations are needed to determine the response of the host rock under the various thermal loading conditions. These analyses are planned but have not yet been done.

The thermal performance of the host rock and the thermal effect on water movement are not well established. Heated block tests are planned underground to assist in determining this information, which is particularly critical to establish the amount of water moved, whether heat pipes occur, and whether convective processes are important.

All of these tests are needed to reduce the uncertainties and develop an improved hydrologic data base. The improved data base is needed to provide sufficient information to validate or verify the equilibrium continuum models being considered at this time for the predictions of thermo-hydrologic behavior.

12.5 COST

A number of uncertainties currently exist in the cost basis, and only some major uncertainties will be specified here. Specifically, it needs to be determined to what extent the size and cost of the site characterization program (ESF, drilling, etc.) change as a function of thermal loading. If a low thermal load strategy is chosen, there needs to be an evaluation of which expansion areas are usable and whether or not there are significant costs incurred to access these expansion areas. Critical information needed for high thermal loads is the cost of the emplacement vehicles, particularly if fully automated vehicles are required, and the cost of shielding. Finally, the costs of monitoring have not been investigated and these costs may vary with thermal load.

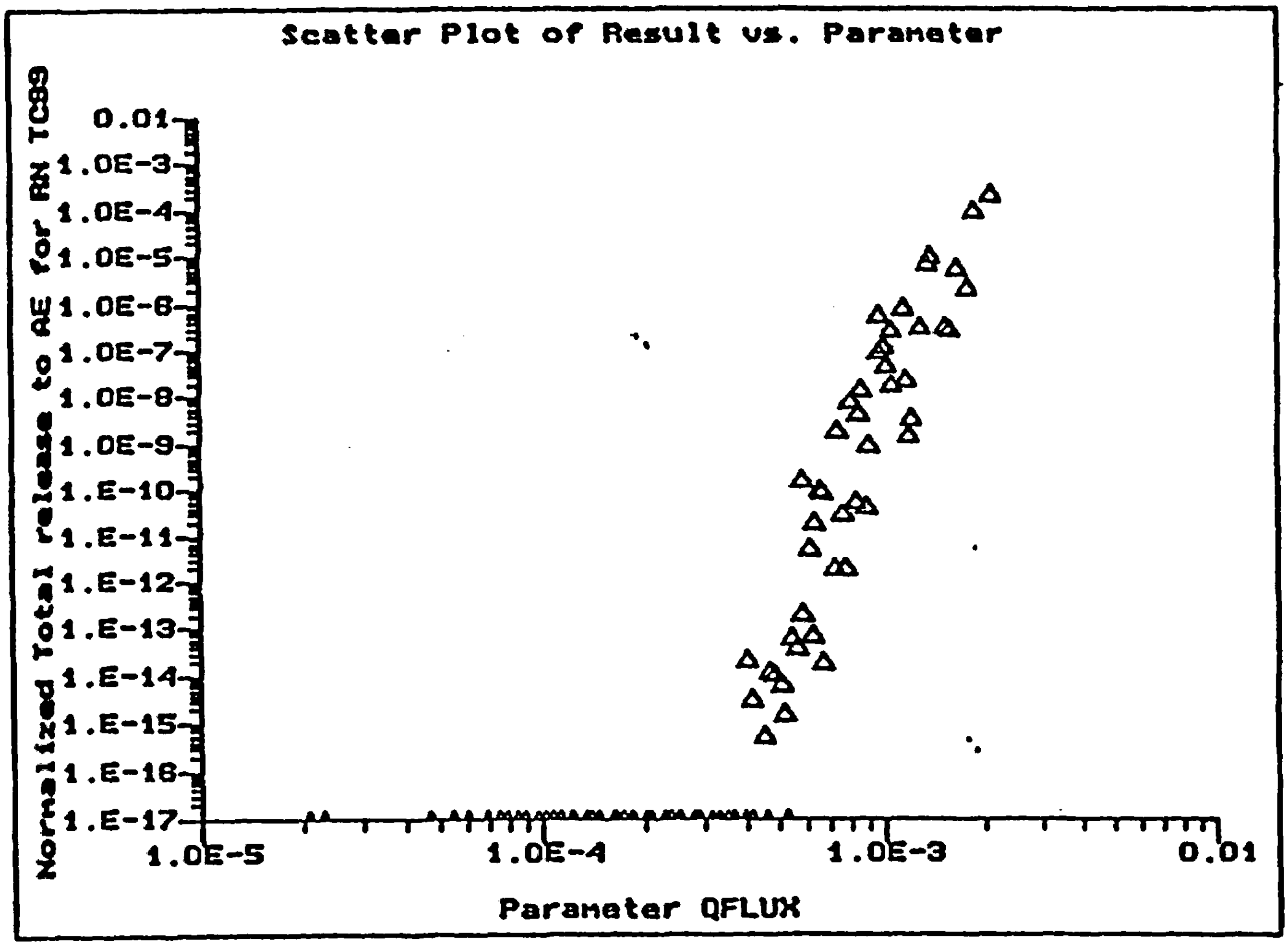


Figure 12-1. Normalized Total Release of Tc99 as a Function of Percolation Flux

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13.2 STANDARDS AND REGULATIONS

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APPENDIX A

ACRONYMS

ACRONYM LIST

AASHTO	American Association of State Highway and Transportation Officials
ACD	Advanced Conceptual Design
ACGIH	American Conference of Government Industrial Hygienists
ACI	American Concrete Institute
ALARA	As Low As Reasonably Achievable
AML	Areal Mass Loading
ANS	American Nuclear Society
ANSI	American National Standards Institute
AO	Annotated Outline
APD	Areal Power Density
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATL	Areal Thermal Loading
AWS	American Welding Society
BLM	U.S. Bureau of Land Management
BNL	Brookhaven National Laboratory
BWR	Boiling Water Reactor
C	Celsius
CA	Construction Authorization
CAC	Configuration Audit Checklist
CCB	Change Control Board
CDA	Controlled Design Assumptions
CDB	Characteristics Data Base
CDR	Conceptual Design Report
CFR	Code of Federal Regulations
CH	Calico Hills
CHn	Calico Hills Non-welded
CI	Configuration Item
CMAA	Crane Manufacturer's Association of America

CMF	Cask Maintenance Facility
COBRA-SFS	Name of a Computer Program
COYOTE	Name of a Computer Program
CRA	Control Rod Assemblies
CRWMS	Civilian Radioactive Waste Management System
CSM	Colorado School of Mines
CTS	Construction and Tunneling Services, Inc.
CWA	Clean Water Act of 1977
DCCG	Diffusion Controlled Gravity Growth
DEIS	Draft Environmental Impact Statement
DHLW	Defense High-Level Waste
DOE	U.S. Department of Energy
DRD	Design Requirements Document
DU	Depleted Uranium
EBDRD	Engineered Barrier Design Requirements Document
EB	Engineered Barrier
EBW	Electron Beam Welding
EED	Equivalent Energy Density
EG&G	EG&G, Inc.
EIA	Energy Information Agency
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ESF	Exploratory Studies Facility
ESFAS	Exploratory Studies Facility Alternatives Study
FEIS	Final Environmental Impact Statement
FEM	Finite Element Method
FIDAP	Fluid Dynamics Analysis Program (Computer Program)
FPCD	Final Procurement and Construction Design
FY	Fiscal Year
GENISES	Geographic Nodal Information Study and Evaluation System (Computer Program)
GMAW	Gas Metal Arc Welding

GROA	Geologic Repository Operations Area
GWd/MTU	Gigawatt-Day per Metric Ton of Uranium
GWTT	Ground Water Travel Time
HEPA	High-Efficiency Particulate Air (filter)
HEATING	Name of a Computer Program
HFS	Human Factors Society
HLF	High Level Finding
HLW	High Level Waste
HLWC	High Level Waste Canisters
HLWG	High Level Waste Glass
HVAC	Heating, Ventilation, and Air Conditioning
IAEA	International Atomic Energy Agency
IC	Integrated Circuits
I-DEAS	Integrated Design Engineering Analysis Software (Computer Program)
ISDOP	In-Small-Drift-On-Pedestal
IES	Institute of Environmental Scientists
IFF	Initial Fuel First
ISDOR	In-Small-Drift-On-Rail
ISR	Initial Summary Report
KBS	Kärnbränslesäkerhet
kW	Kilowatt
LA	License Application
LAD	License Application Design
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory
LLNL	Lawrence Livermore National Laboratory
LSA	Logistics Support Analysis
LWR	Light Water Reactor
MATPRO	Name of a Computer Program
MCNP	Monte Carlo Neutron and Photon Transport Core
MGDS	Mined Geologic Disposal System

MIC	Microbiologically Influenced Corrosion
MMB	Metallic Multibarrier
M&O	Management and Operating Contractor
MPa	Megapascals
MPC	Multi-Purpose Canister
MRS	Monitored Retrievable Storage
MSHA	Mine Safety and Health Administration
MTA	Main Test Area
MTIHM	Metric Ton of Initial Heavy Metal
MTL	Main Test Level
MTU	Metric Tons of Uranium
MWD	Megawatt Days
NAC	Nuclear Assurance Corporation
NDE	Non-Destructive Examination
NEPA	National Environmental Policy Act of 1969
NFPA	National Fire Protection Association
NGW	Narrow Gap Welding
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
NTS	Nevada Test Site
NWPA	Nuclear Waste Policy Act of 1982
NWTRB	Nuclear Waste Technical Review Board
OCRWM	Office of Civilian Radioactive Waste Management
OFF	Oldest Fuel First
OGR	Office of Geologic Repositories
ORNL RSIC	Oak Ridge National Laboratory Radiation Shielding Information Center
OSHA	Occupational Safety and Health Administration
OSTS	Office of Storage and Transportation Systems
PA	Performance Assessment
PACS	Planning and Control System (Computer Program)
PATRAN	Name of a Computer Program

PCF	Penetrating Cone Fracture
PNL	Pacific Northwest Laboratory
POC	Products of Combustion
PPA	Proposed Program Approach
PTn	Paintbrush Tuff Non-welded
PWR	Pressurized Water Reactor
Q	Quality Factor
QA	Quality Assurance
QAP	Quality Administrative Procedure
QARD	Quality Assurance Requirements and Description
RADDB	Radiological Database
RCP	Regulatory Compliance Plan
RCRA	Resource Conservation and Recovery Act of 1976
RD	Requirements Document
RDRD	Repository Design Requirements Document
REECo	Reynolds Electrical and Engineering Company, Inc.
RIB	Reference Information Base
RIP	Repository Integration Plan
RSIC	Radiation Shielding Information Center
RMC	Rock Mass Category
RMR	Rock Mass Rating
RN	Radionuclides
ROD	Record of Decision
RQD	Rock Quality Designation
RSN	Raytheon Services Nevada
SAE	Society of Automotive Engineers
SCC	Substantially Complete Containment
SCP-CD	Site Characterization Plan Conceptual Design
SCP-CDR	Site Characterization Plan Conceptual Design Report
SDRC	Structural Dynamics Research Corporation
SFAs	Spent Fuel Assemblies

SIP	Scientific Investigation Plan
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SNF	Spent Nuclear Fuel
SNL	Sandia National Laboratories
SRR	Site Recommendation Report (DOE/HO 3-1)
TCLP	Toxicity Characteristic Leaching Procedure
TBD	To Be Determined
TBM	Tunnel Boring Machine
TBR	To Be Resolved
TBV	To Be Verified
TDPP	Technical Document Preparation Plan
T/M	Thermal/Mechanical
T&MSS	Technical and Management Support Services
TOPAZ	Name of a Computer Program
TP	Test Plan
TRD	Technical Requirements Document
TS	Topopah Spring
TSL	Topopah Spring Level
TSLCC	Total System Life Cycle Cost
TSPA	Total System Performance Assessment
TSS	Technical Site Suitability
TSw	Topopah Spring welded
UCF	Uncanistered Fuel
UCRL	University of California Research Laboratory
UCS	Uniaxial or Unconfined Compressive Strength
UE	Underground, Exploratory (Drill Hole Designation)
UNS	Unified Numbering System for Metals and Alloys
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
USW	Underground, Southern Nevada, Waste (Drill Hole Designation)
UZ	Unsaturated Zone

V-TOUGH	Vectorized Transport of Unsaturated Groundwater and Heat (Computer Program)
WA	Waste Acceptance
WF	Weighting Factors
WHB	Waste Handling Building
WP/EBS	Waste Package/Engineered Barrier System
WP	Waste Package
WPD	Waste Package Development
YFF	Youngest Fuel First
YFF10	Youngest Fuel First 10 Years or Older
YMIM	Yucca Mountain Integrating Model
YMP	Yucca Mountain Site Characterization Project
YMSCO	Yucca Mountain Site Characterization Office

APPENDIX B

WASTE PACKAGE CONCEPTUAL DESIGNS

WASTE PACKAGE CONCEPTUAL DESIGNS

Design layouts for six specific designs, representing three waste package design concepts, are included in this appendix, located in a separate bound figure set. The large 21 PWR/40 BWR MPC disposal container is shown on Figures B.1-1 through B.1-4. The intermediate 12 PWR/24 BWR MPC disposal container is shown on Figures B.1-5 through B.1-8. The 21 PWR waste package with interlocking basket is shown on Figures B.2-1 through B.2-15. The 12 PWR waste package with interlocking basket is shown on Figures B.2-16 through B.2-30. The 12 PWR waste package with tube type basket is shown on Figures B.3-1 through B.3-11. The 24 BWR waste package with tube type basket is shown on Figures B.3-12 through B.3-21.

APPENDIX C

SPECIFICATION LIST

SPECIFICATION LIST

Information for this appendix has not been developed to date. This work will be performed before completion of ACD in FY 1996.

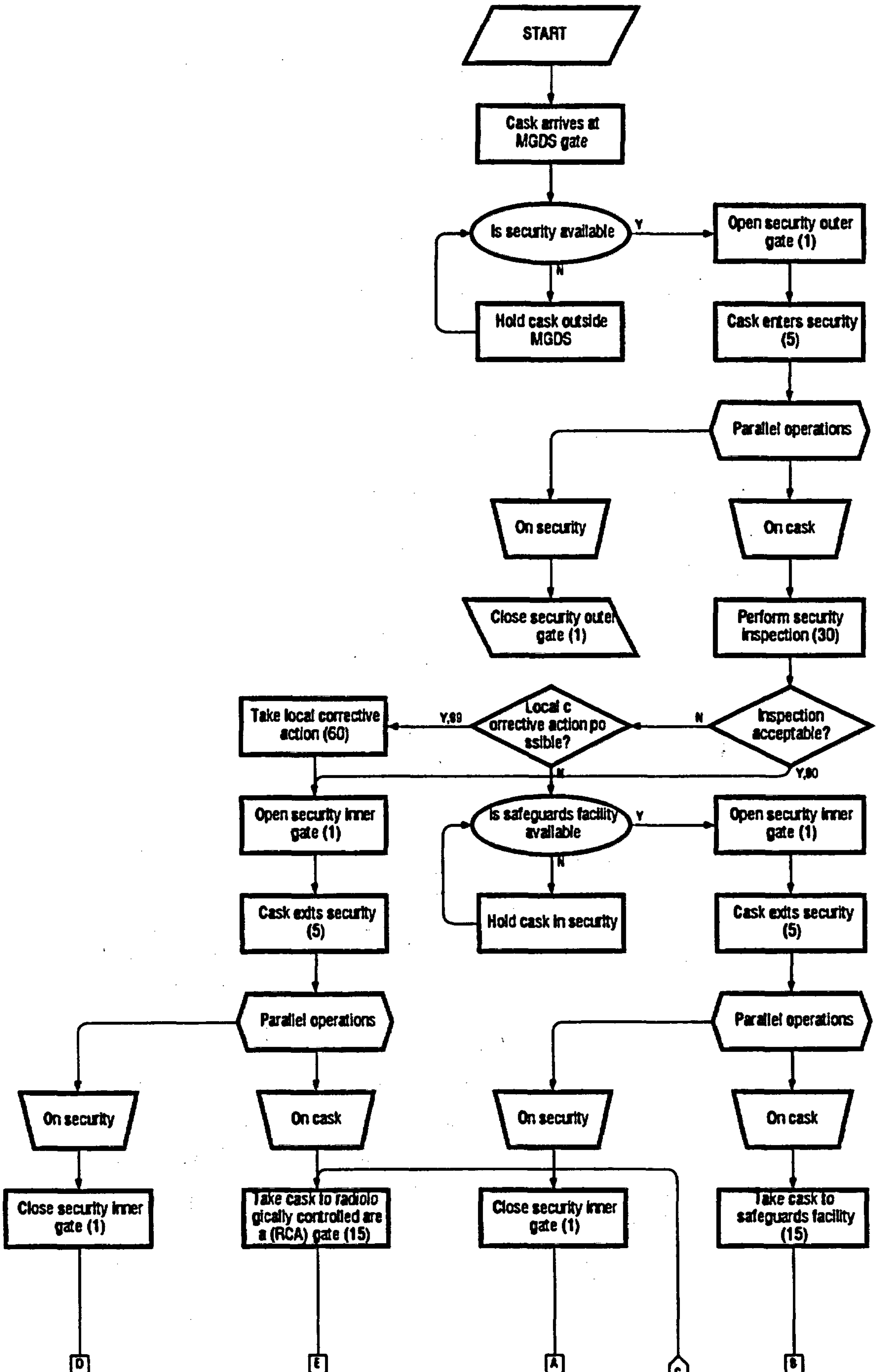
EQUIPMENT LIST

Information for this appendix has not been developed to date. This work will be performed before completion of ACD in FY 1996.

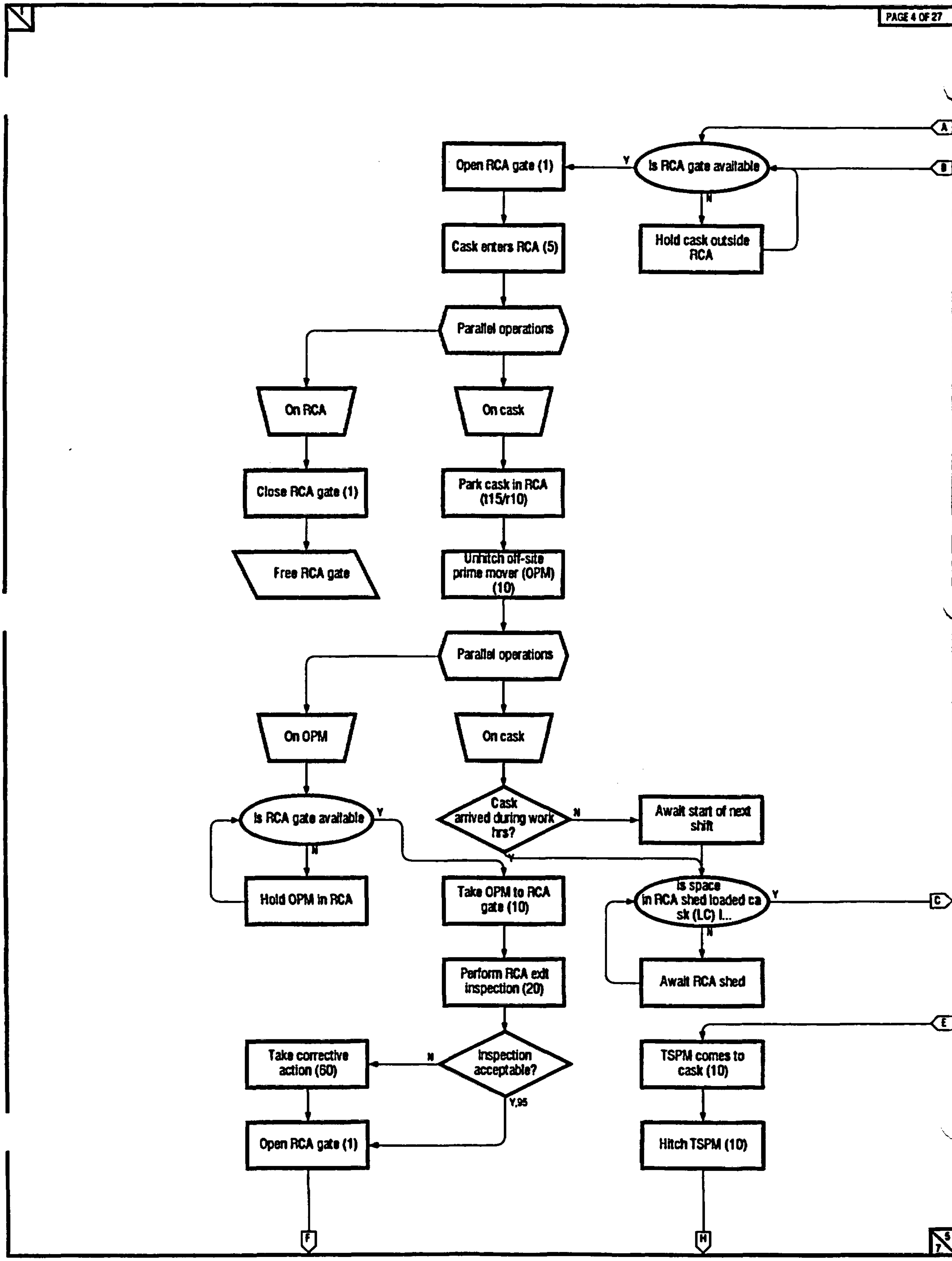
APPENDIX E

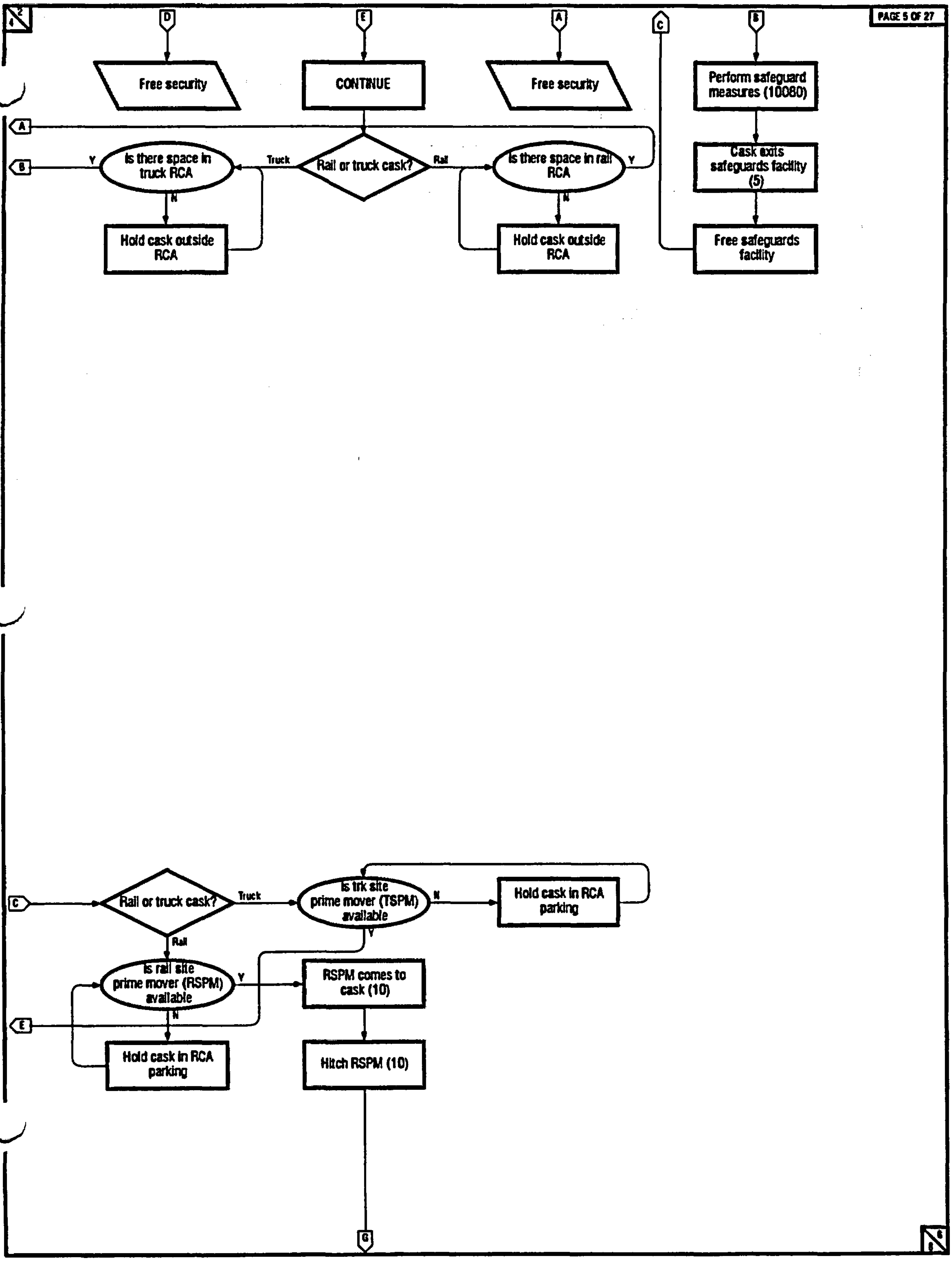
WHB OPERATIONS FLOW CHARTS

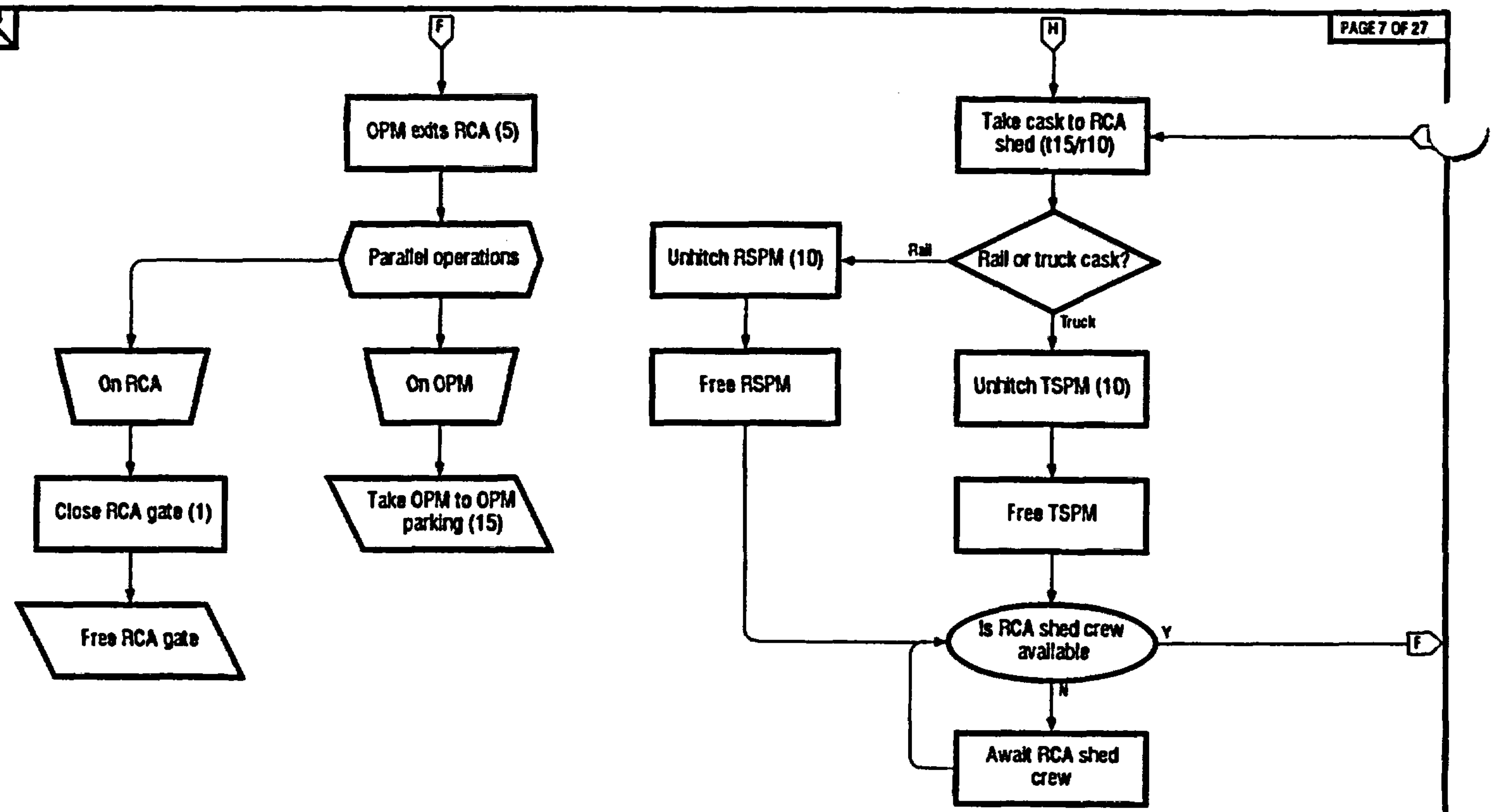
Loaded Cask Operations

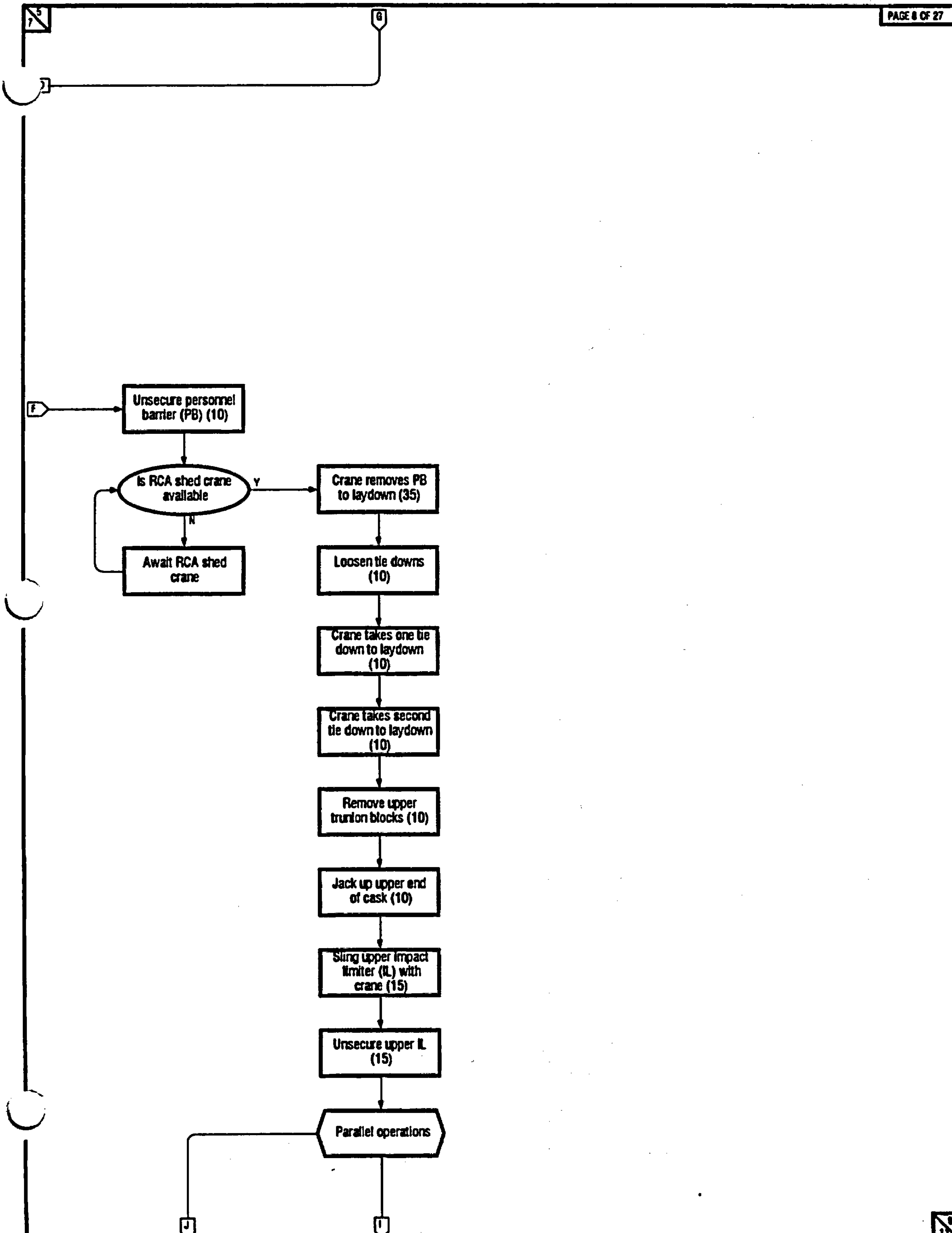


START
Cask arrives at MGDS gate
Is security available
Y
N
Hold cask outside MGDS
Open security outer gate (1)
Cask enters security (5)
Parallel operations
On security
On cask
Close security outer gate (1)
Perform security inspection (30)
Inspection acceptable?
N
Y,90
Local c orrective action po ssible?
Y,99
N
Take local corrective action (60)
Open security inner gate (1)
Is safeguards facility available
Y
N
Hold cask in security
Open security inner gate (1)
Cask exits security (5)
Cask exits security (5)
Parallel operations
Parallel operations
On security
On cask
On security
On cask
Close security inner gate (1)
Take cask to radiolo gically controlled are a (RCA) gate (15)
Close security inner gate (1)
Take cask to safeguards facility (15)
D
E
A
C
B

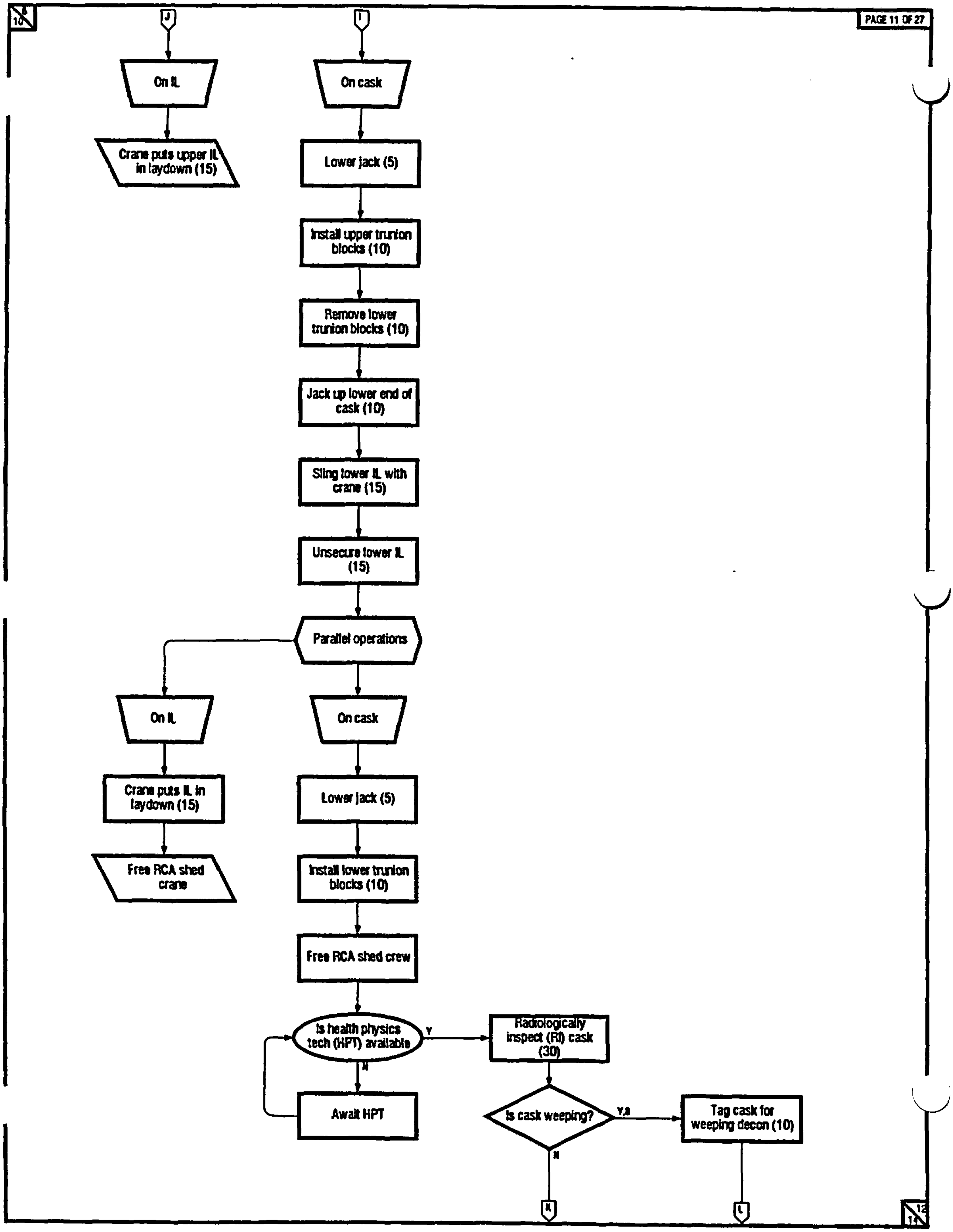

A
B
Is RCA gate available
Y
N
Open RCA gate (1)
Hold cask outside RCA
Cask enters RCA (5)
Parallel operations
On RCA
On cask
Close RCA gate (1)
Park cask in RCA (t15/r10)
Free RCA gate
Unhitch off-site prime mover (OPM) (10)
Parallel operations
On OPM
On cask
Is RCA gate available
Y
N
Cask arrived during work hrs?
N
Y
Await start of next shift
Hold OPM in RCA
Take OPM to RCA gate (10)
Is space in RCA shed loaded ca sk (LC) l...
Y
N
C
Perform RCA exit inspection (20)
Await RCA shed
E
Take corrective action (60)
N
Inspection acceptable?
Y,95
TSPM comes to cask (10)
Open RCA gate (1)
Hitch TSPM (10)
F
H
5
7

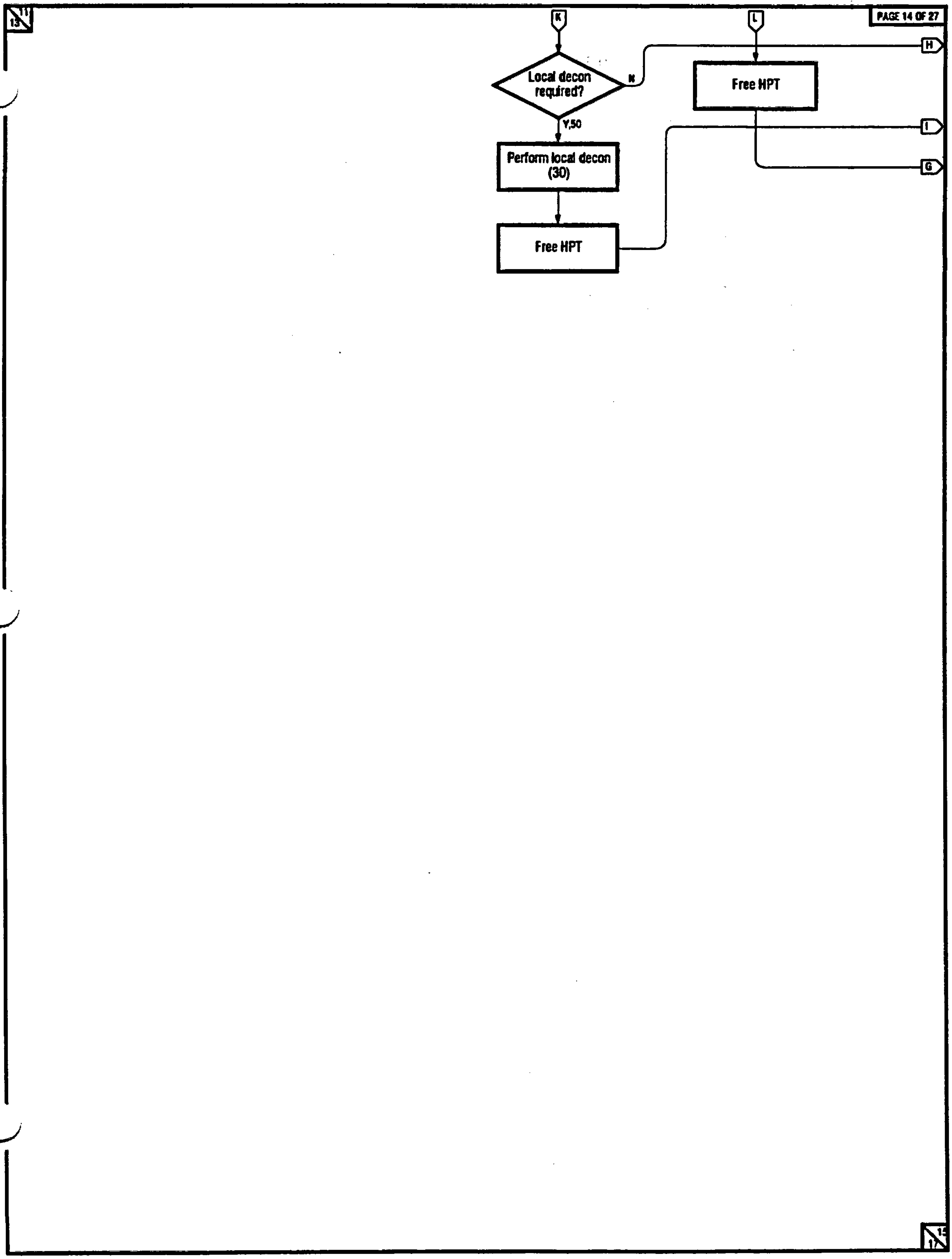

D
E
A
C
B
Free security
CONTINUE
Free security
Perform safeguard measures (10080)
A
B
Y
Is there space in truck RCA
Truck
Rail or truck cask?
Rail
Is there space in rail RCA
Y
Cask exits safeguards facility (5)
N
N
Hold cask outside RCA
Hold cask outside RCA
Free safeguards facility
C
Rail or truck cask?
Truck
Is trk site prime mover (TSPM) available
N
Hold cask in RCA parking
Y
Rail
Is rail site prime mover (RSPM) available
Y
RSPM comes to cask (10)
E
N
Hold cask in RCA parking
Hitch RSPM (10)
G

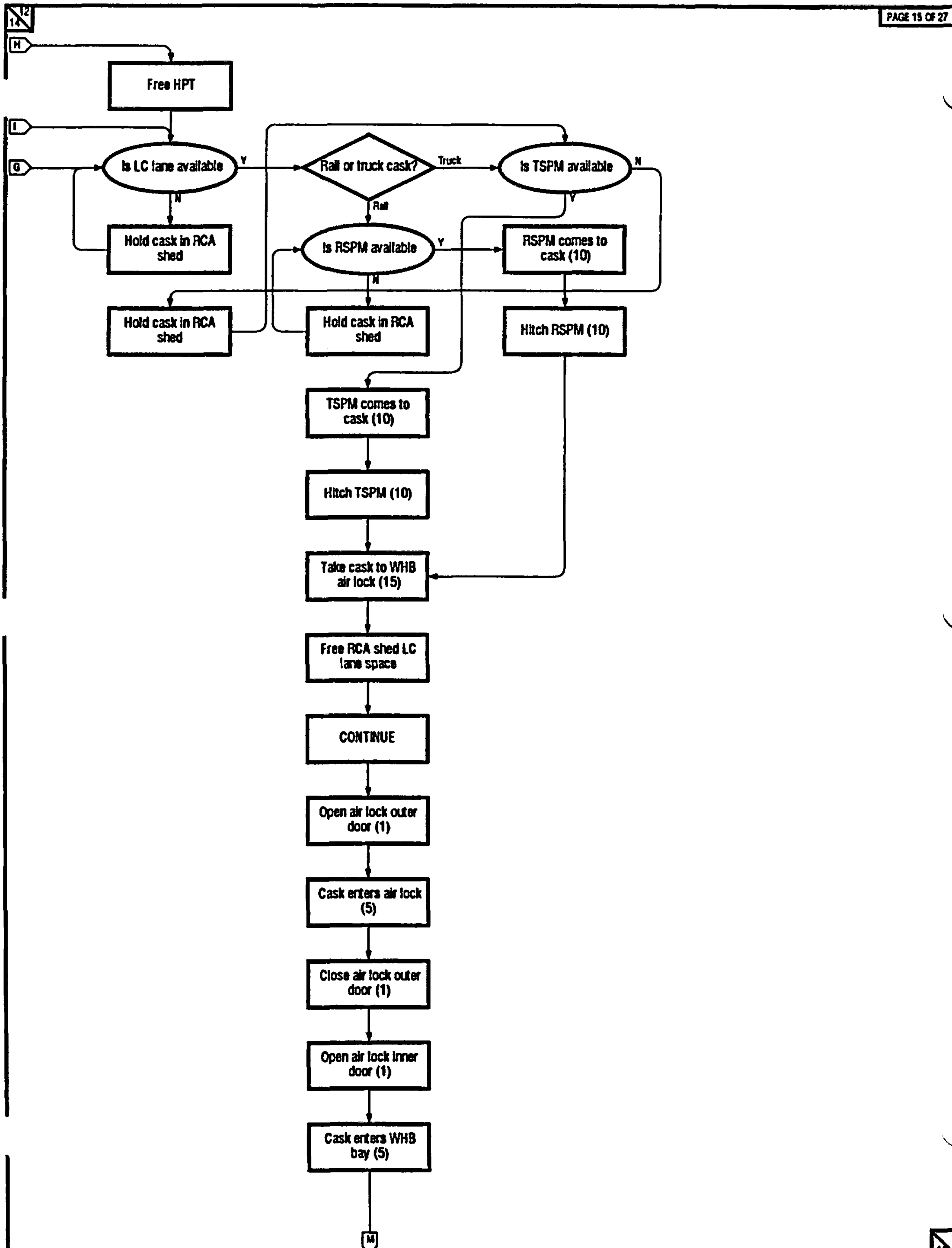

F
H
OPM exits RCA (5)
Take cask to RCA shed (t15/r10)
Parallel operations
Unhitch RSPM (10)
Rail
Rail or truck cask?
Truck
On RCA
On OPM
Free RSPM
Unhitch TSPM (10)
Close RCA gate (1)
Take OPM to OPM parking (15)
Free TSPM
Free RCA gate
Is RCA shed crew available
Y
N
F
Await RCA shed crew

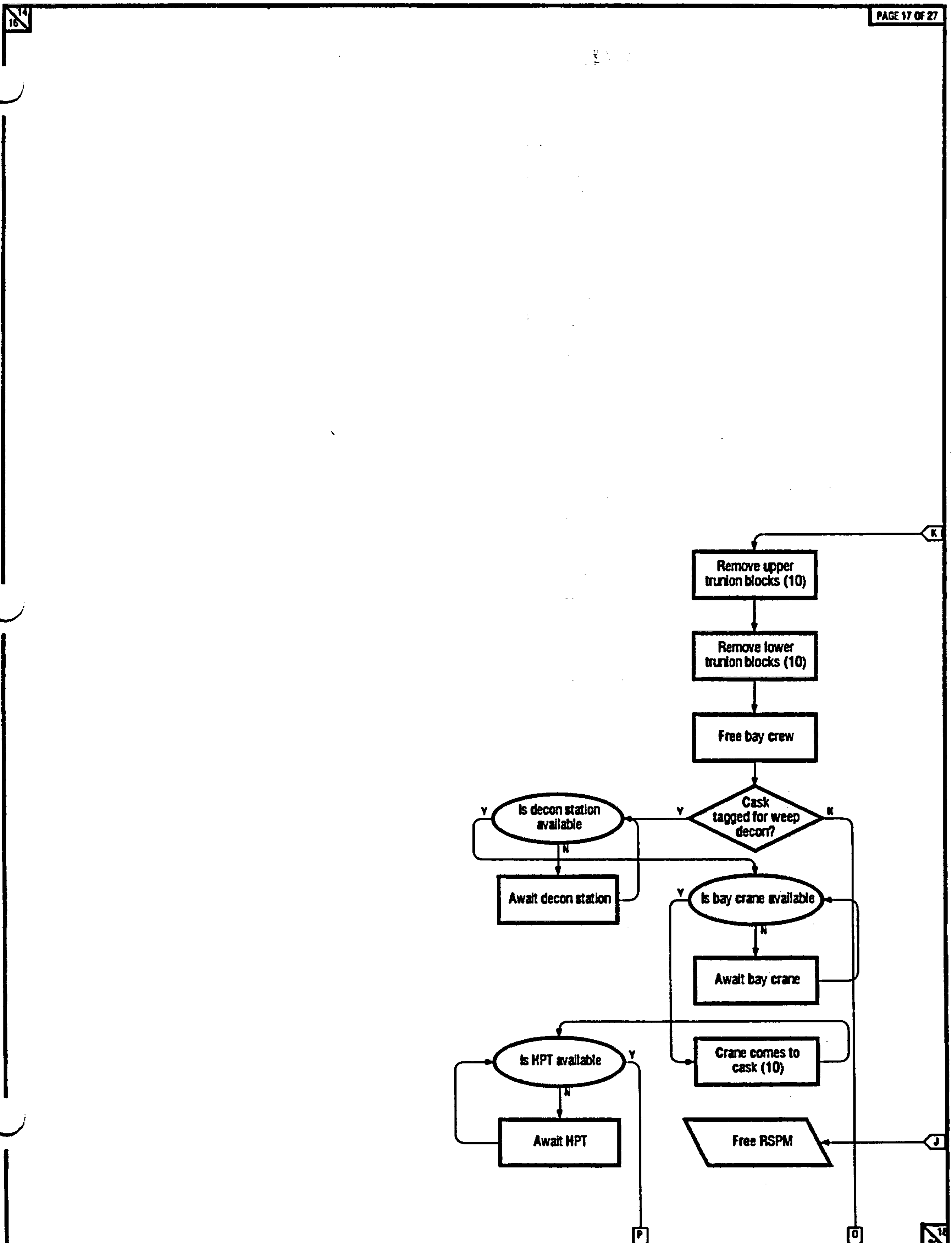


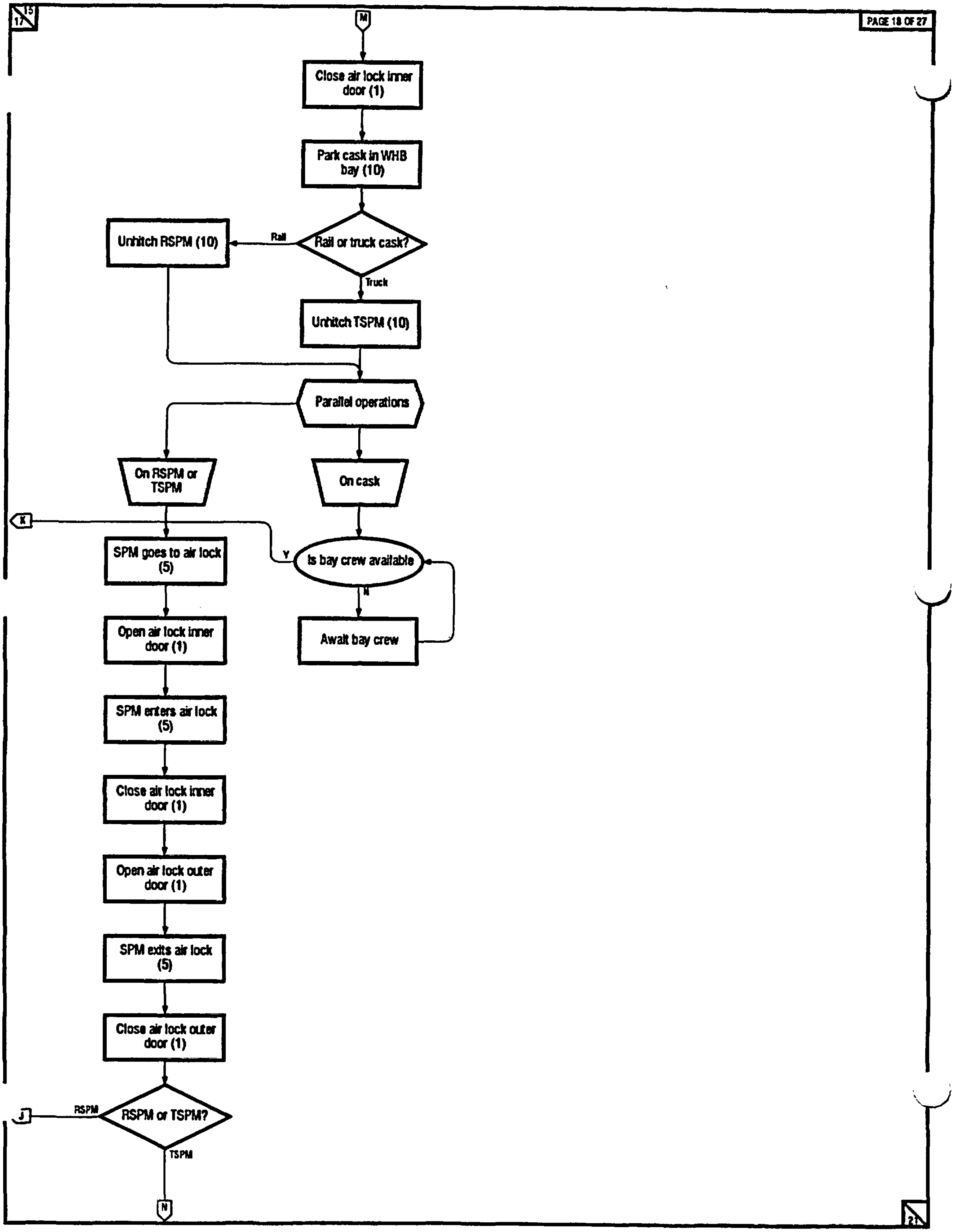
G
F
Unsecure personnel barrier (PB) (10)
Is RCA shed crane available
Y
N
Await RCA shed crane
Crane removes PB to laydown (35)
Loosen tie downs (10)
Crane takes one tie down to laydown (10)
Crane takes second tie down to laydown (10)
Remove upper trunion blocks (10)
Jack up upper end of cask (10)
Sling upper impact limiter (IL) with crane (15)
Unsecure upper IL (15)
Parallel operations
J
I

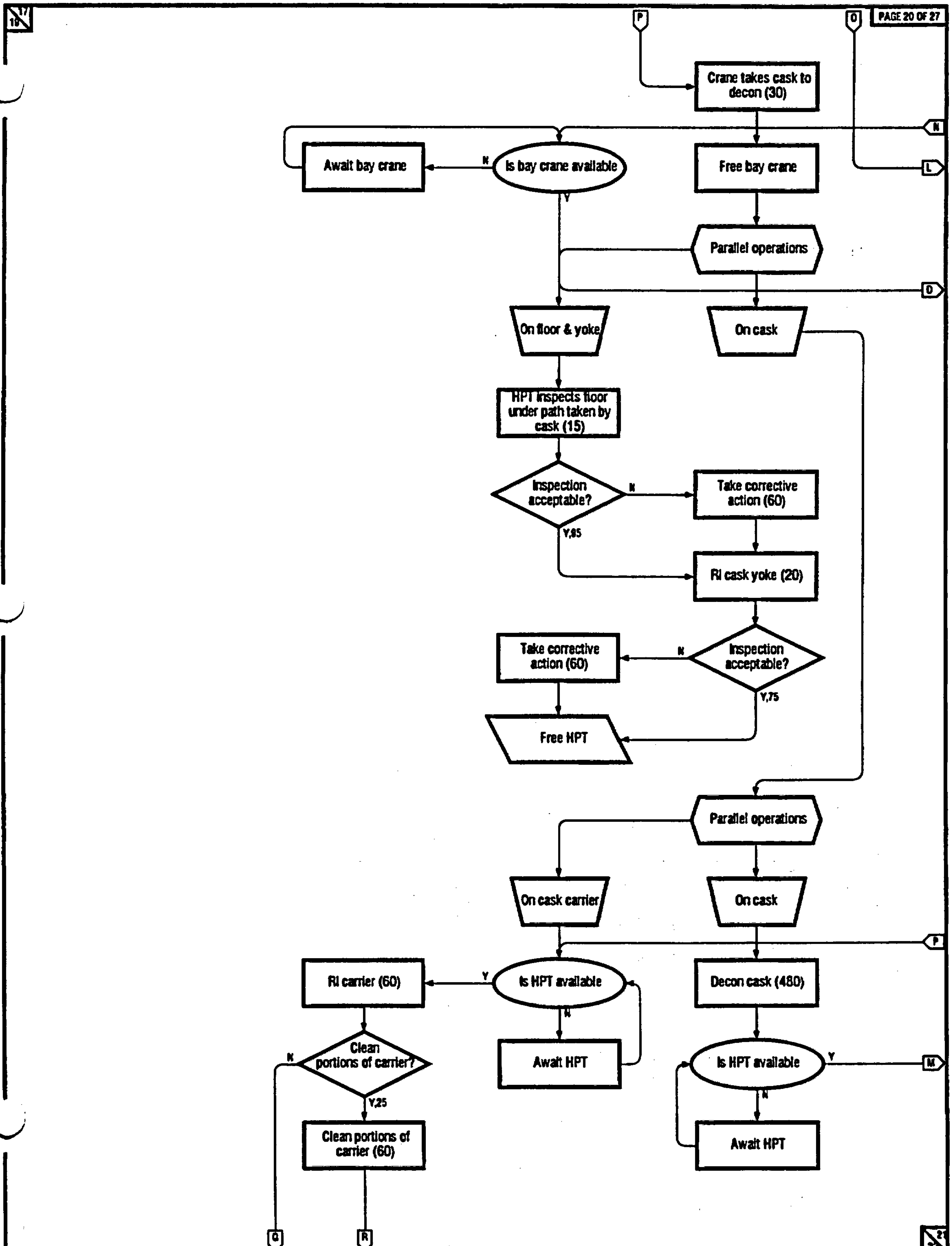

J
I
On IL
On cask
Crane puts upper IL in laydown (15)
Lower jack (5)
Install upper trunion blocks (10)
Remove lower trunion blocks (10)
Jack up lower end of cask (10)
Sling lower IL with crane (15)
Unsecure lower IL (15)
Parallel operations
On IL
On cask
Crane puts IL in laydown (15)
Lower jack (5)
Free RCA shed crane
Install lower trunion blocks (10)
Free RCA shed crew
Is health physics tech (HPT) available
Y
N
Await HPT
Radiologically inspect (RI) cask (30)
Is cask weeping?
Y,a
N
Tag cask for weeping decon (10)
K
L

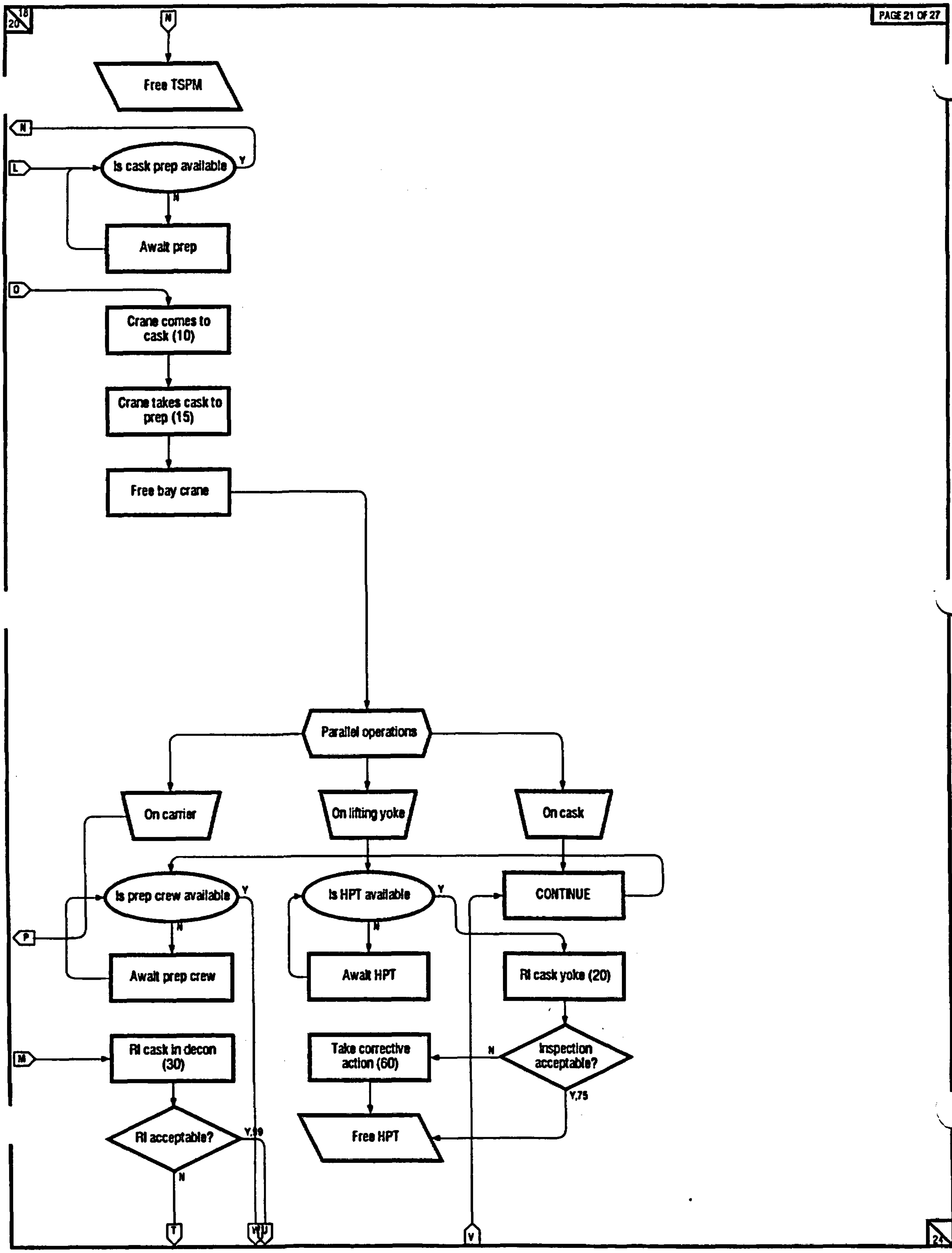

13
11
K
L
Local decon required?
N
Y,50
Perform local decon (30)
Free HPT
Free HPT
H
I
G
15
17

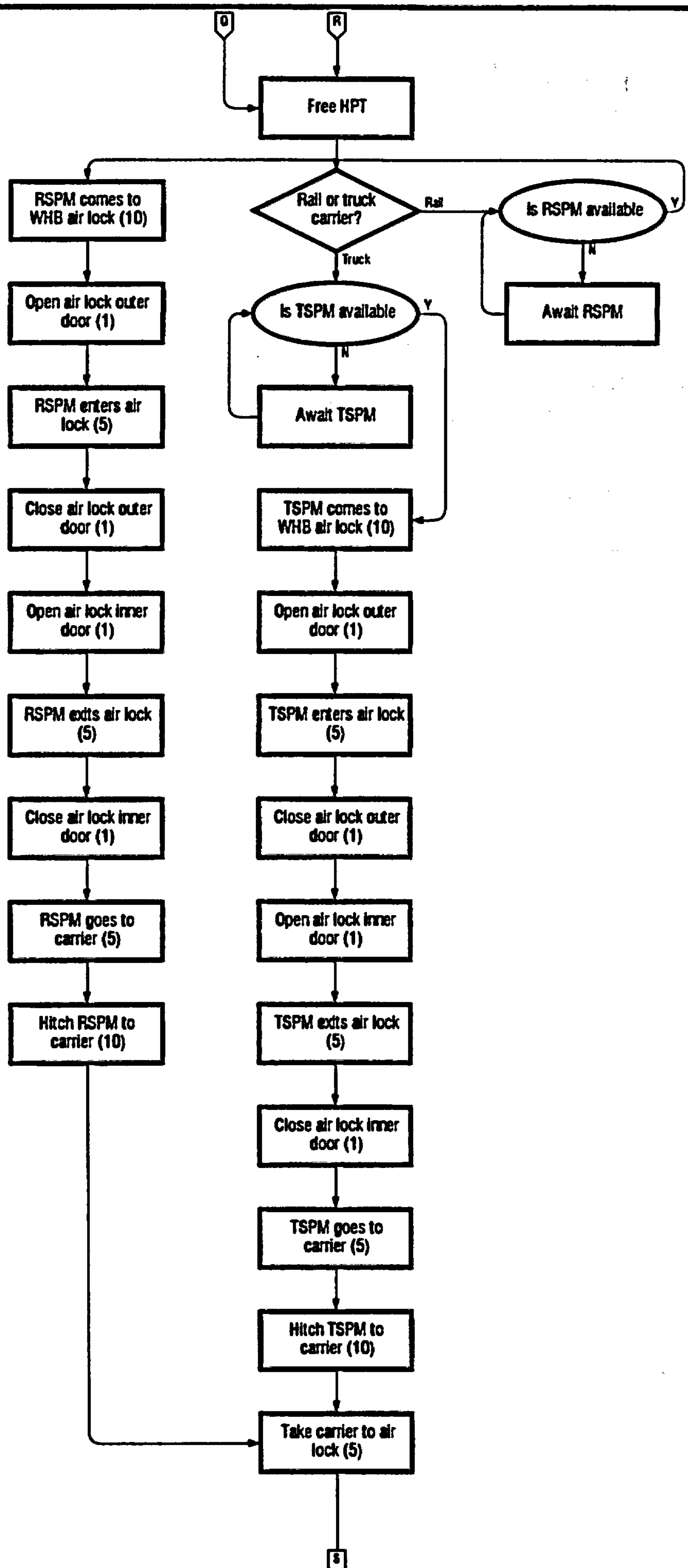

12
14
H
I
G
Free HPT
Is LC lane available
Y
N
Hold cask in RCA shed
Rail or truck cask?
Truck
Rail
Is TSPM available
N
Y
Is RSPM available
Y
N
RSPM comes to cask (10)
Hold cask in RCA shed
Hold cask in RCA shed
Hitch RSPM (10)
TSPM comes to cask (10)
Hitch TSPM (10)
Take cask to WHB air lock (15)
Free RCA shed LC lane space
CONTINUE
Open air lock outer door (1)
Cask enters air lock (5)
Close air lock outer door (1)
Open air lock inner door (1)
Cask enters WHB bay (5)
M
16

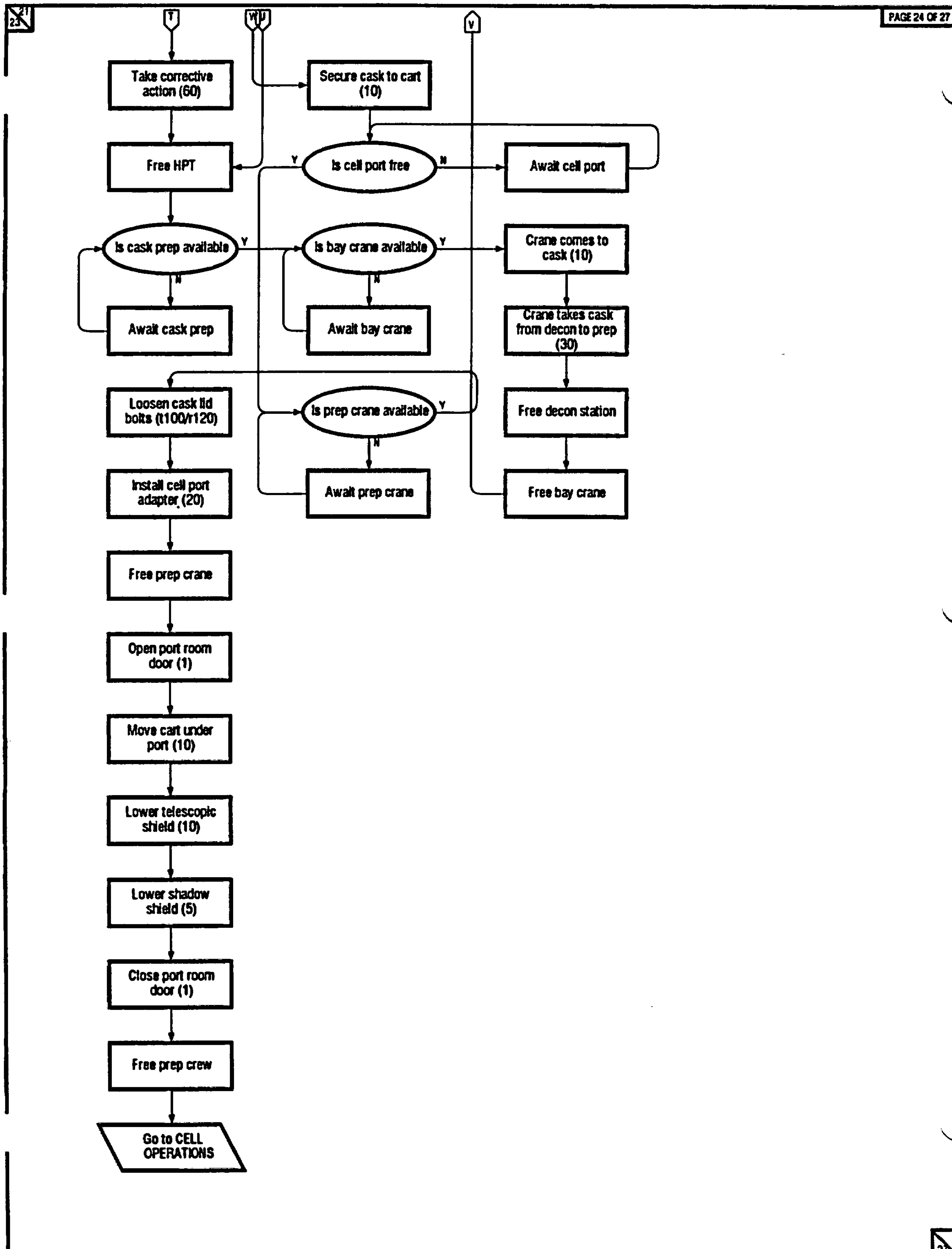

14
16
K
Remove upper trunion blocks (10)
Remove lower trunion blocks (10)
Free bay crew
Cask tagged for weep decon?
Y
N
Is decon station available
Y
N
Await decon station
Is bay crane available
Y
N
Await bay crane
Crane comes to cask (10)
Is HPT available
Y
N
Await HPT
Free RSPM
J
P
O
18
20

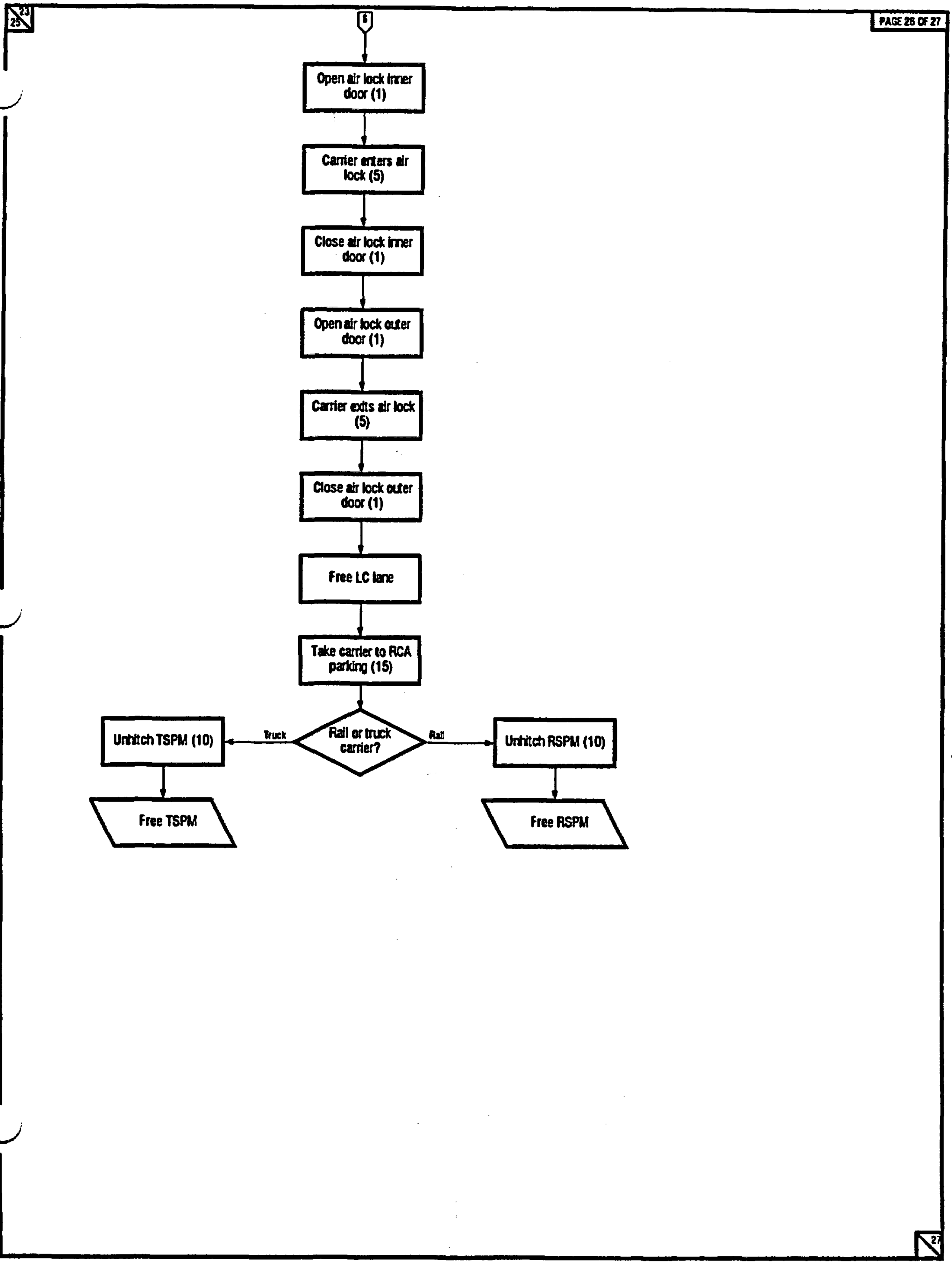

15
17
M
Close air lock inner door (1)
Park cask in WHB bay (10)
Rail or truck cask?
Rail
Truck
Unhitch RSPM (10)
Unhitch TSPM (10)
Parallel operations
On RSPM or TSPM
On cask
K
Y
Is bay crew available
N
Await bay crew
SPM goes to air lock (5)
Open air lock inner door (1)
SPM enters air lock (5)
Close air lock inner door (1)
Open air lock outer door (1)
SPM exits air lock (5)
Close air lock outer door (1)
RSPM or TSPM?
RSPM
J
TSPM
N
21


17
19
P
O
Crane takes cask to decon (30)
N
Await bay crane
N
Is bay crane available
Free bay crane
L
Y
Parallel operations
D
On floor & yoke
On cask
HPT inspects floor under path taken by cask (15)
Inspection acceptable?
N
Take corrective action (60)
Y,95
RI cask yoke (20)
Take corrective action (60)
N
Inspection acceptable?
Y,75
Free HPT
Parallel operations
On cask carrier
On cask
P
RI carrier (60)
Y
Is HPT available
Decon cask (480)
N
Clean portions of carrier?
Await HPT
Is HPT available
Y
M
N
Y,25
N
Clean portions of carrier (60)
Await HPT
Q
R
21
23

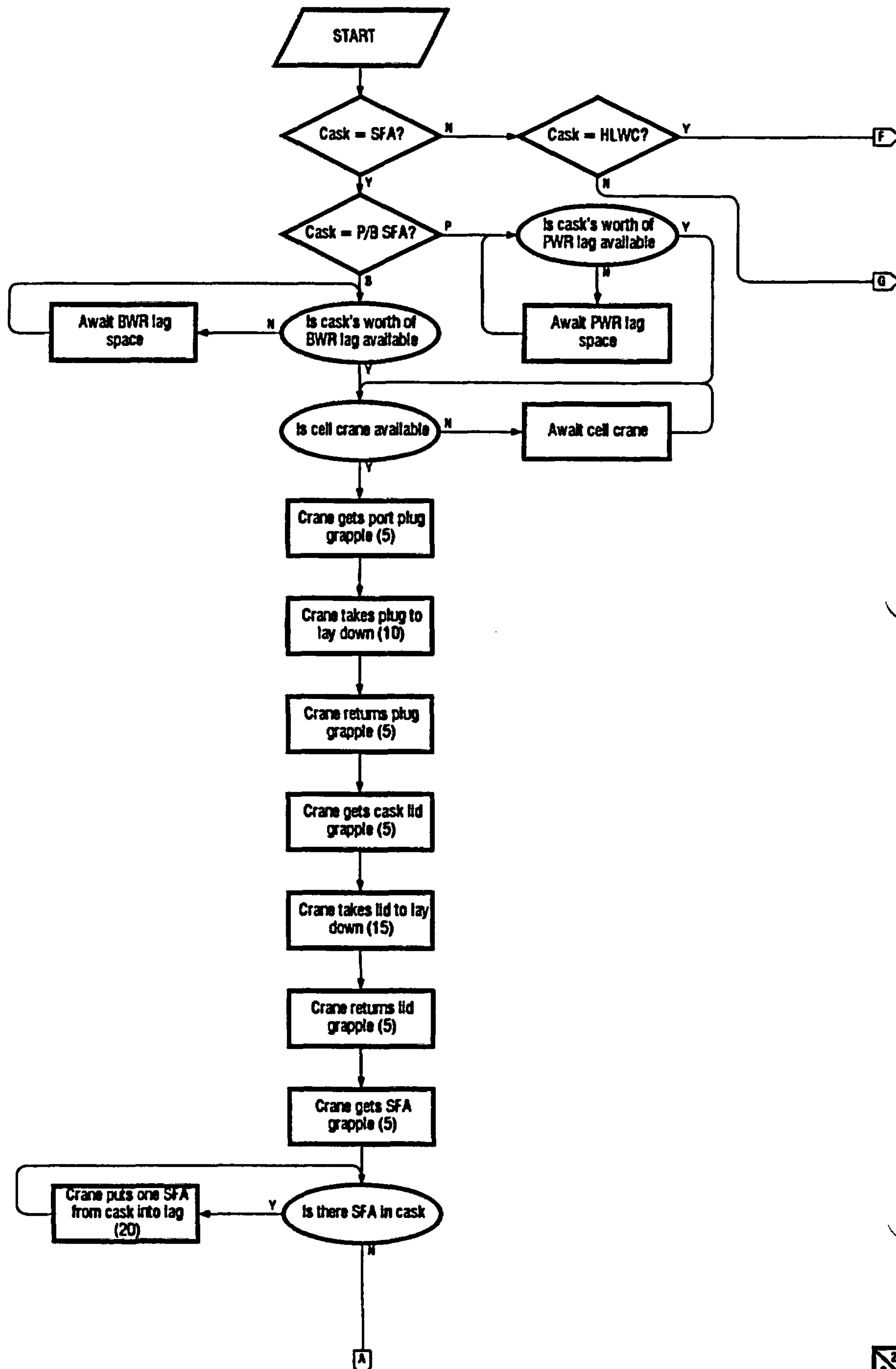

18
20
N
Free TSPM
N
L
Is cask prep available
Y
N
Await prep
O
Crane comes to cask (10)
Crane takes cask to prep (15)
Free bay crane
Parallel operations
On carrier
On lifting yoke
On cask
Is prep crew available
Y
N
P
Await prep crew
Is HPT available
Y
N
Await HPT
CONTINUE
RI cask yoke (20)
M
RI cask in decon (30)
RI acceptable?
Y,99
N
Take corrective action (60)
N
Inspection acceptable?
Y,75
Free HPT
T
W
U
V
24

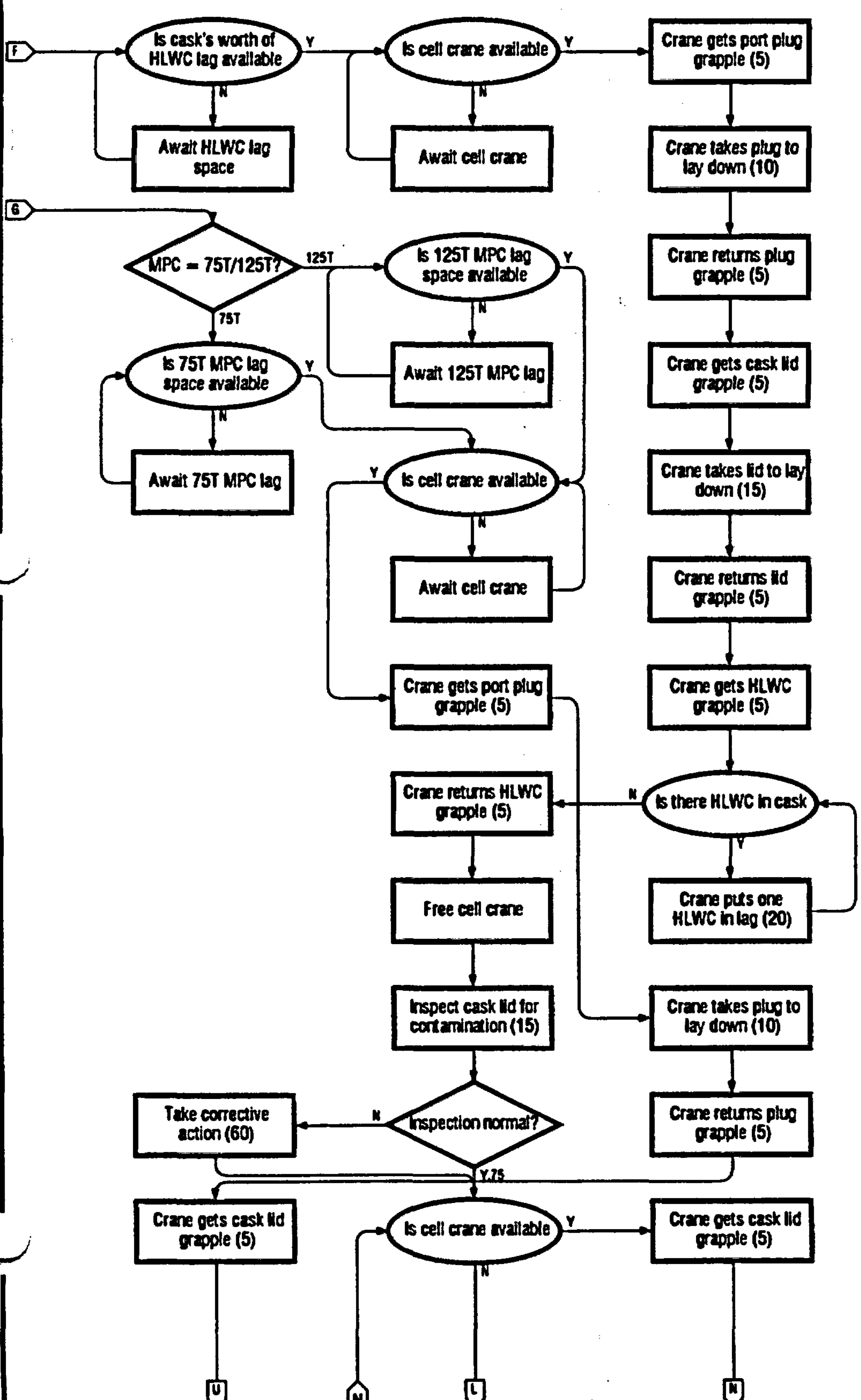

Q
R
Free HPT
Rail or truck carrier?
Rail
Truck
Is RSPM available
Y
N
Await RSPM
RSPM comes to WHB air lock (10)
Open air lock outer door (1)
RSPM enters air lock (5)
Close air lock outer door (1)
Open air lock inner door (1)
RSPM exits air lock (5)
Close air lock inner door (1)
RSPM goes to carrier (5)
Hitch RSPM to carrier (10)
Is TSPM available
Y
N
Await TSPM
TSPM comes to WHB air lock (10)
Open air lock outer door (1)
TSPM enters air lock (5)
Close air lock outer door (1)
Open air lock inner door (1)
TSPM exits air lock (5)
Close air lock inner door (1)
TSPM goes to carrier (5)
Hitch TSPM to carrier (10)
Take carrier to air lock (5)
S

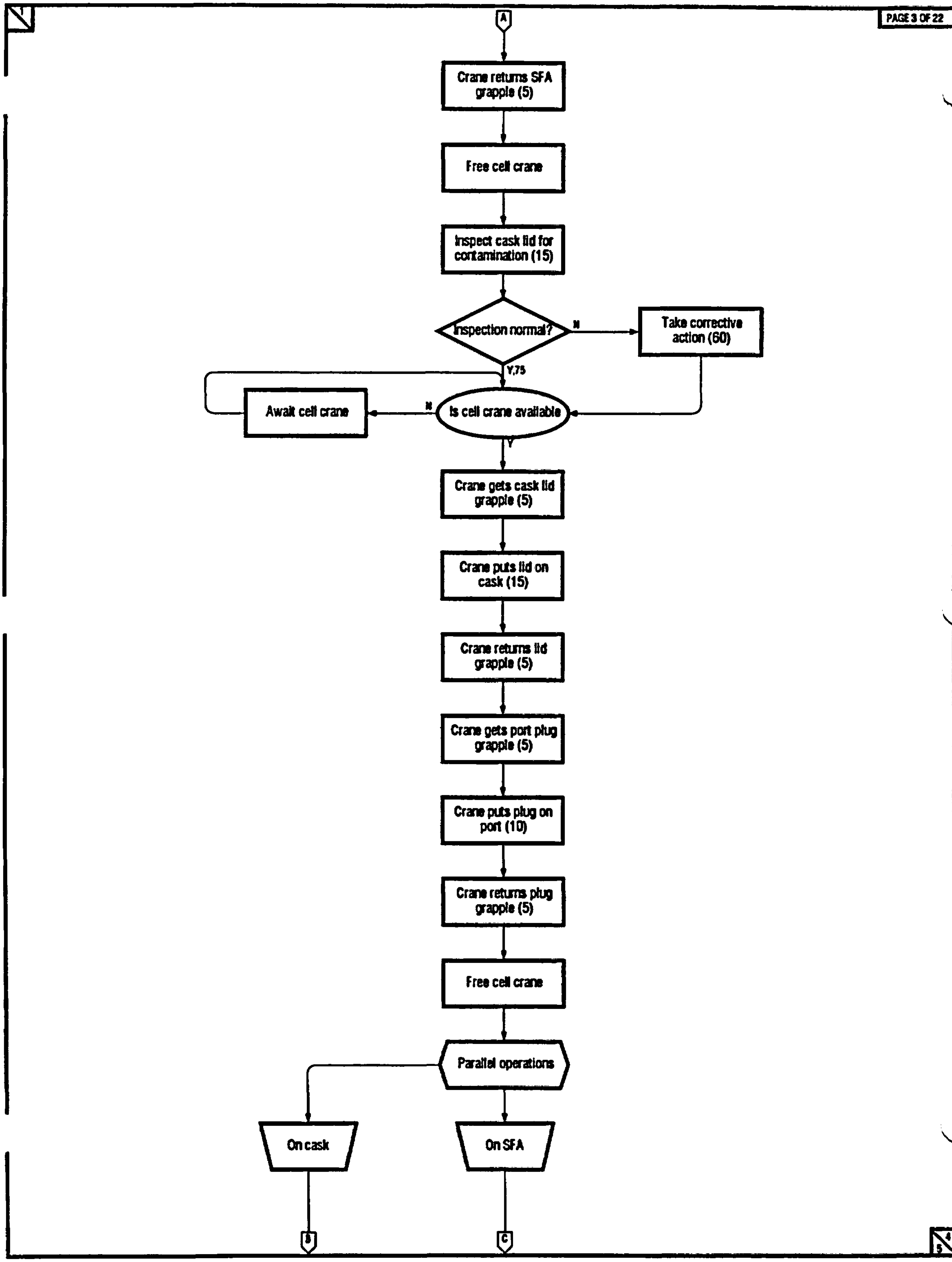

T
W
U
V
Take corrective action (60)
Secure cask to cart (10)
Free HPT
Is cell port free
Y
N
Await cell port
Is cask prep available
Y
N
Await cask prep
Is bay crane available
Y
N
Await bay crane
Crane comes to cask (10)
Crane takes cask from decon to prep (30)
Free decon station
Free bay crane
Loosen cask lid bolts (t100/r120)
Is prep crane available
Y
N
Await prep crane
Install cell port adapter (20)
Free prep crane
Open port room door (1)
Move cart under port (10)
Lower telescopic shield (10)
Lower shadow shield (5)
Close port room door (1)
Free prep crew
Go to CELL OPERATIONS

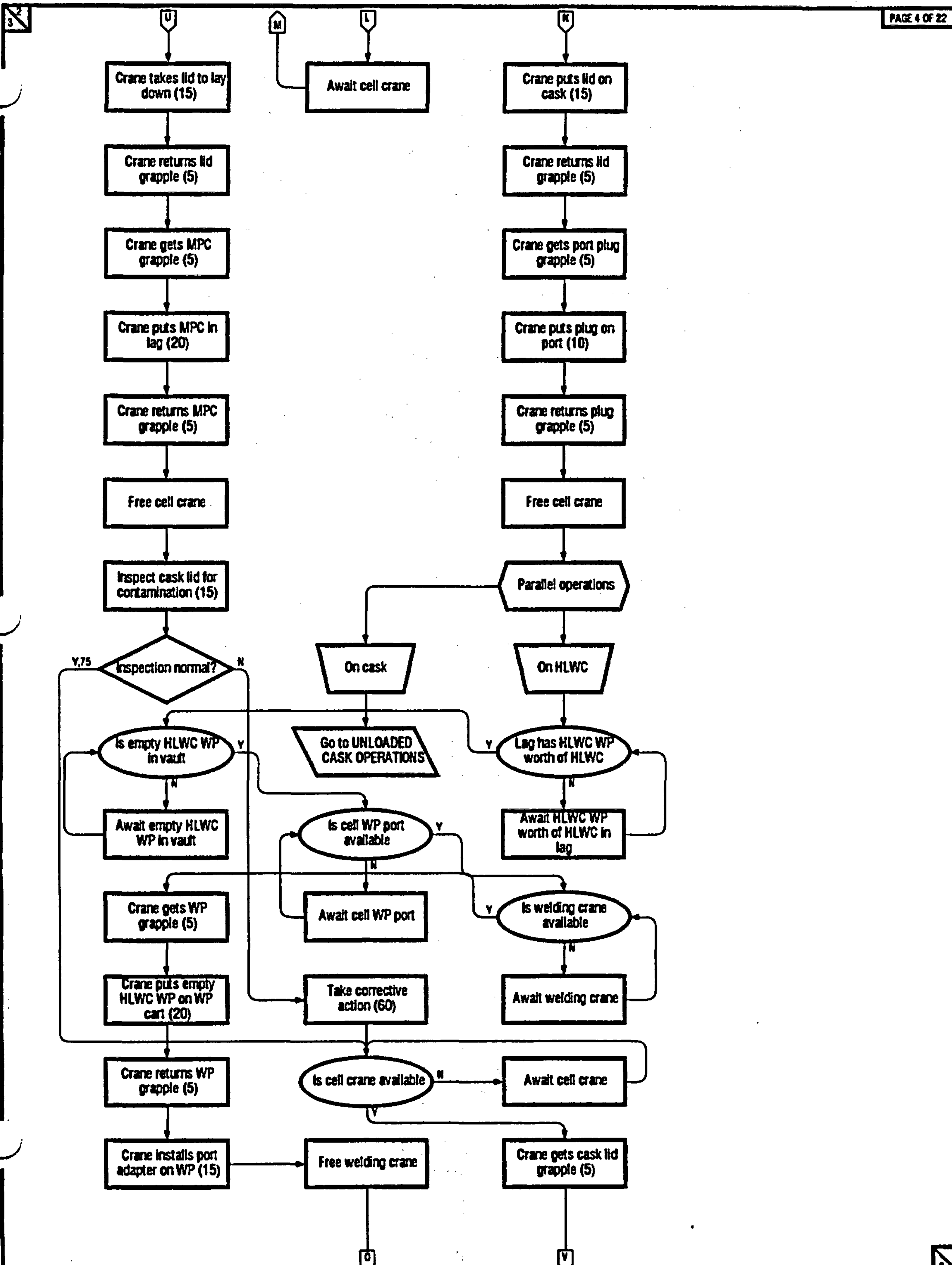

23
25
5
Open air lock inner door (1)
Carrier enters air lock (5)
Close air lock inner door (1)
Open air lock outer door (1)
Carrier exits air lock (5)
Close air lock outer door (1)
Free LC lane
Take carrier to RCA parking (15)
Rail or truck carrier?
Truck
Rail
Unhitch TSPM (10)
Unhitch RSPM (10)
Free TSPM
Free RSPM
27

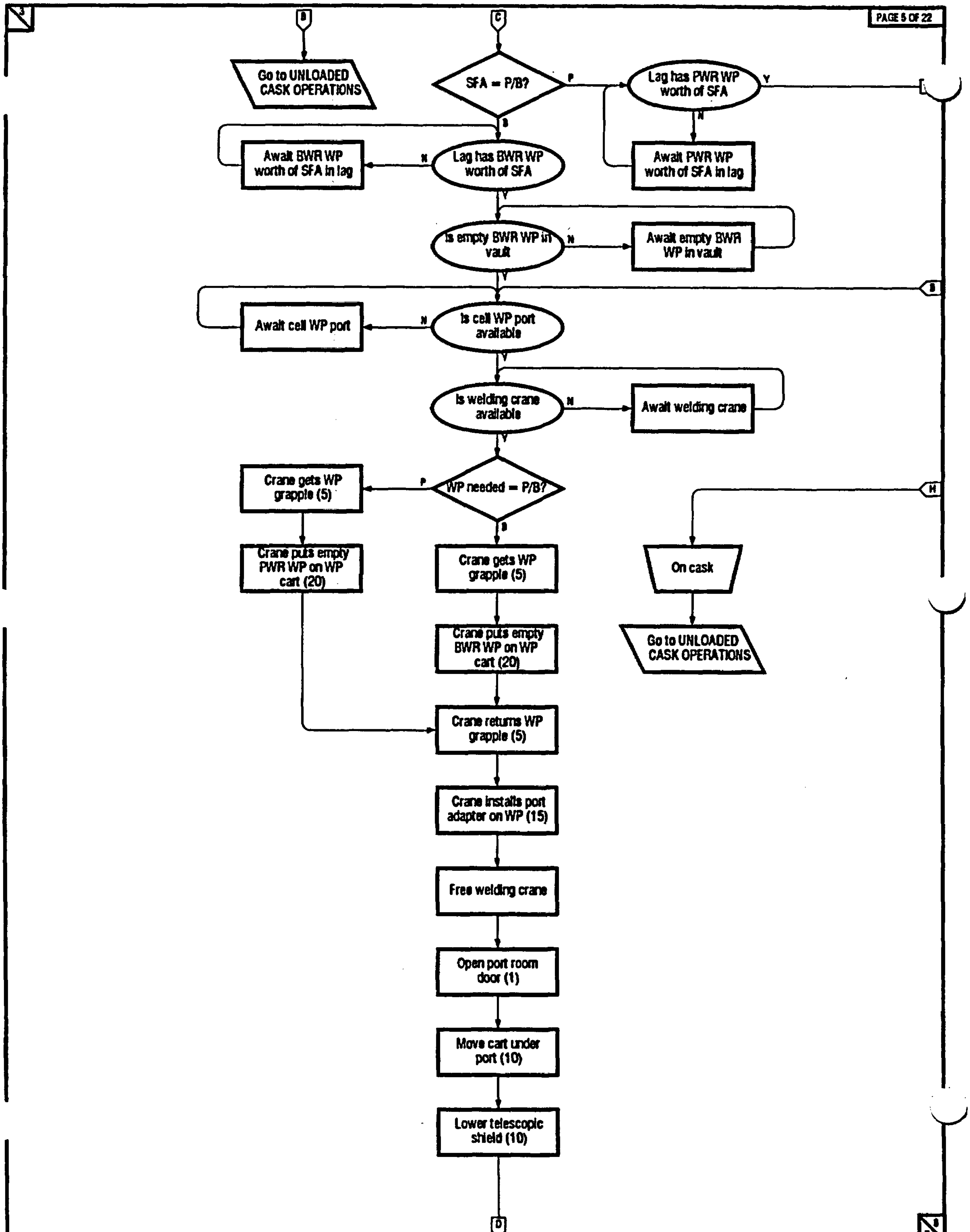
Cell Operations

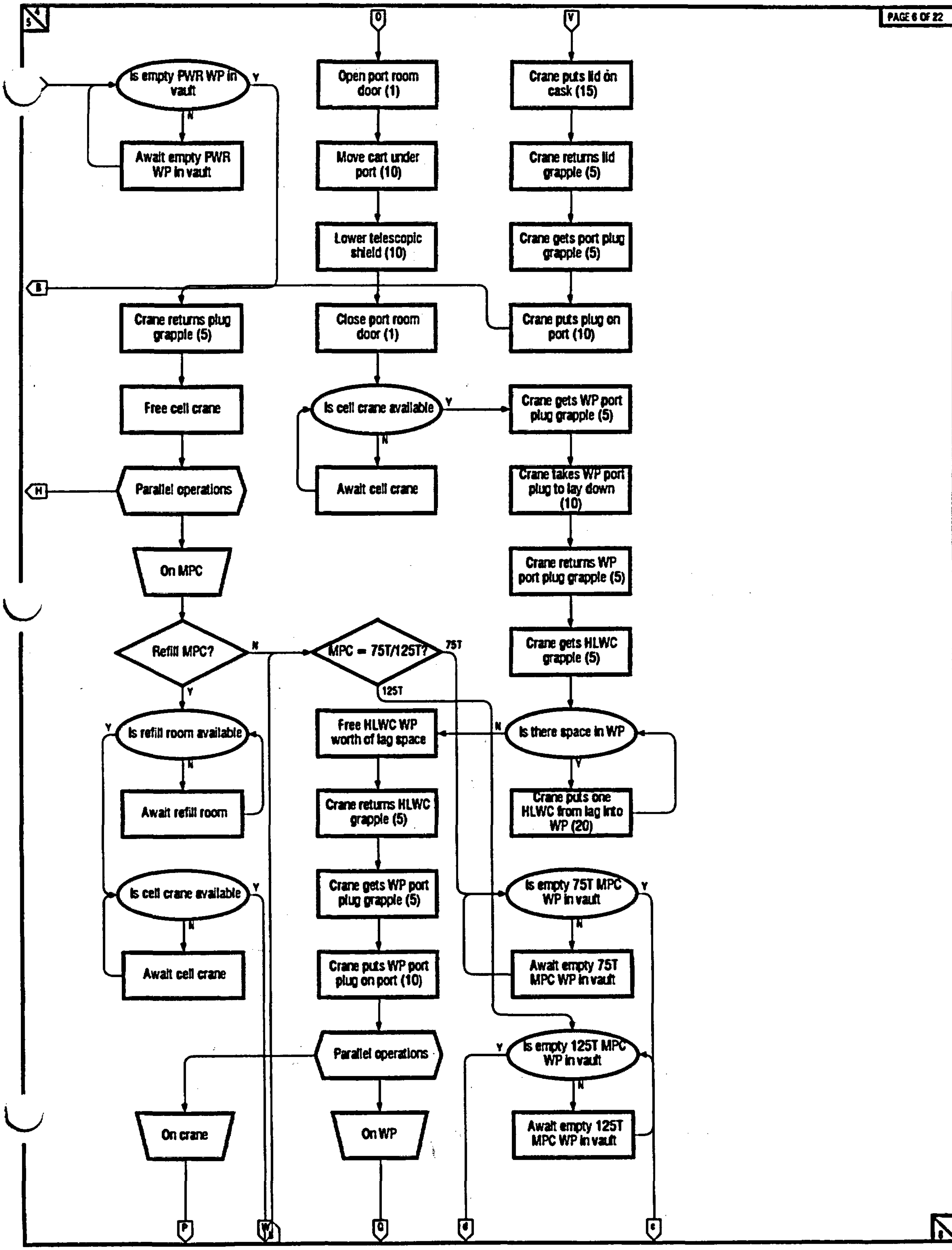


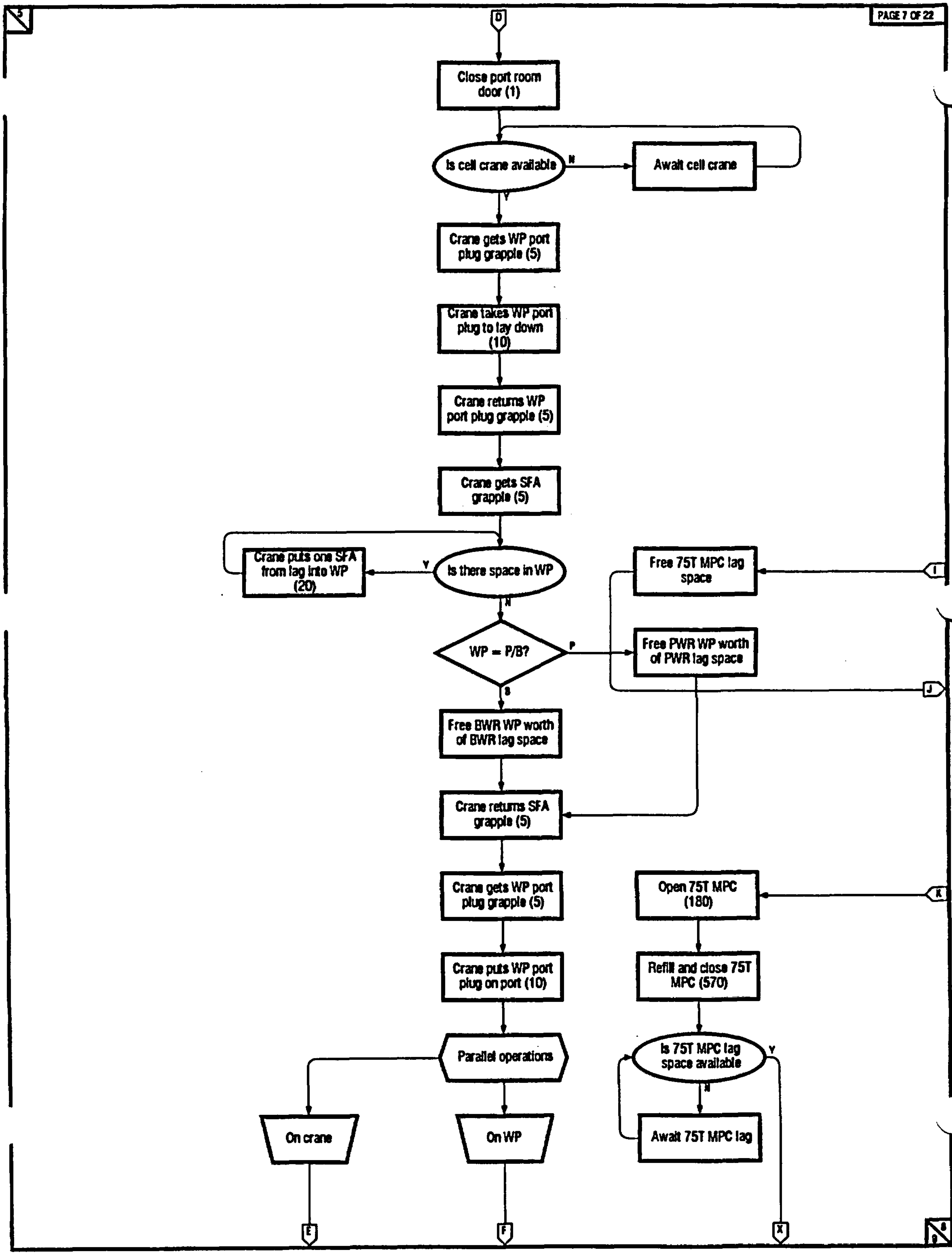

F
Is cask's worth of HLWC lag available
Y
N
Await HLWC lag space
Is cell crane available
Y
N
Await cell crane
Crane gets port plug grapple (5)
Crane takes plug to lay down (10)
Crane returns plug grapple (5)
Crane gets cask lid grapple (5)
Crane takes lid to lay down (15)
Crane returns lid grapple (5)
Crane gets HLWC grapple (5)
Is there HLWC in cask
N
Y
Crane puts one HLWC in lag (20)
Crane returns HLWC grapple (5)
Free cell crane
Inspect cask lid for contamination (15)
Inspection normal?
N
Take corrective action (60)
Y,75
6
MPC = 75T/125T?
125T
75T
Is 125T MPC lag space available
Y
N
Await 125T MPC lag
Is 75T MPC lag space available
Y
N
Await 75T MPC lag
Is cell crane available
Y
N
Await cell crane
Crane gets port plug grapple (5)
Crane takes plug to lay down (10)
Crane returns plug grapple (5)
Crane gets cask lid grapple (5)
Is cell crane available
Y
N
Crane gets cask lid grapple (5)
U
M
L
N

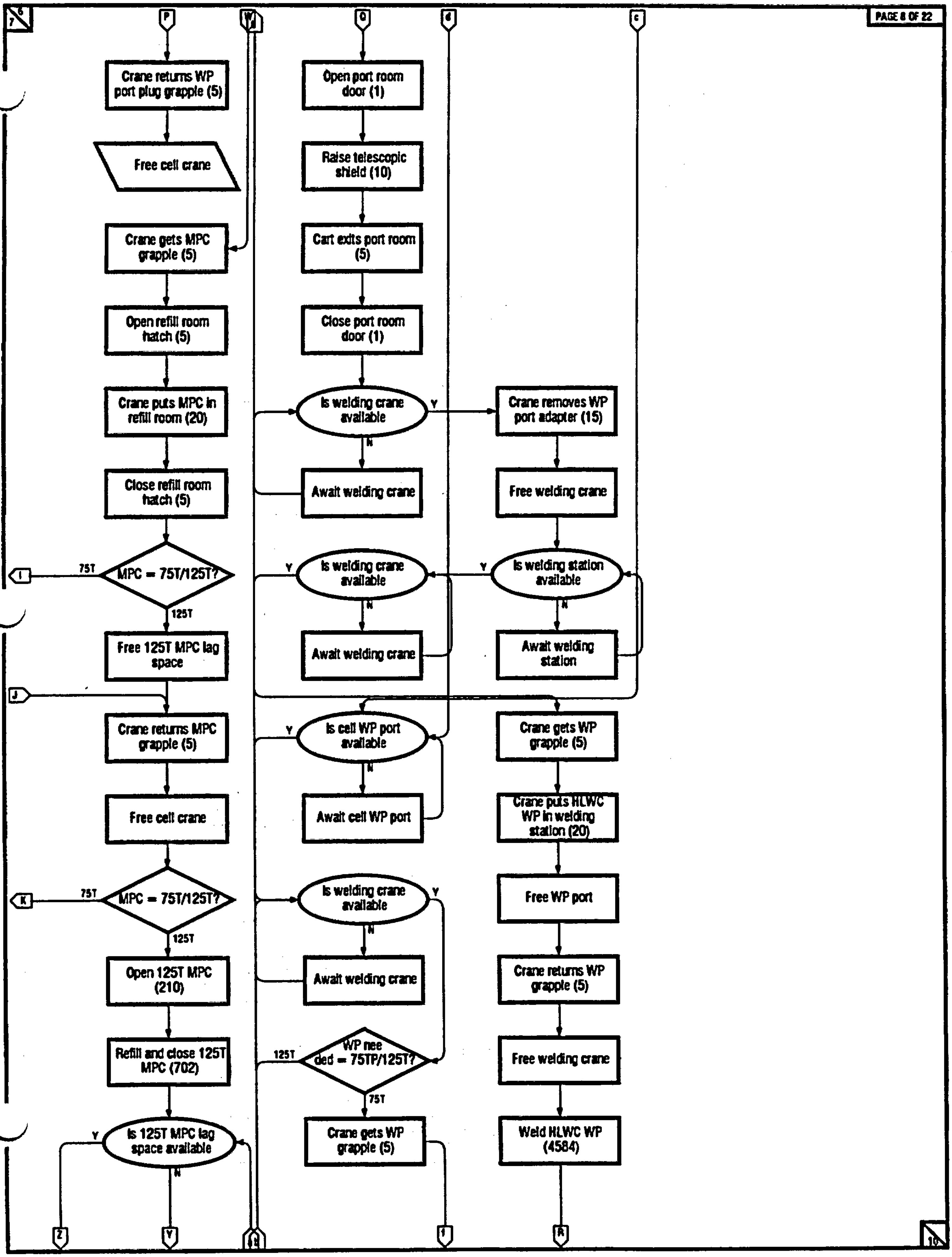

A
Crane returns SFA grapple (5)
Free cell crane
Inspect cask lid for contamination (15)
Inspection normal?
N
Take corrective action (60)
Y,75
Is cell crane available
N
Await cell crane
Y
Crane gets cask lid grapple (5)
Crane puts lid on cask (15)
Crane returns lid grapple (5)
Crane gets port plug grapple (5)
Crane puts plug on port (10)
Crane returns plug grapple (5)
Free cell crane
Parallel operations
On cask
On SFA
B
C

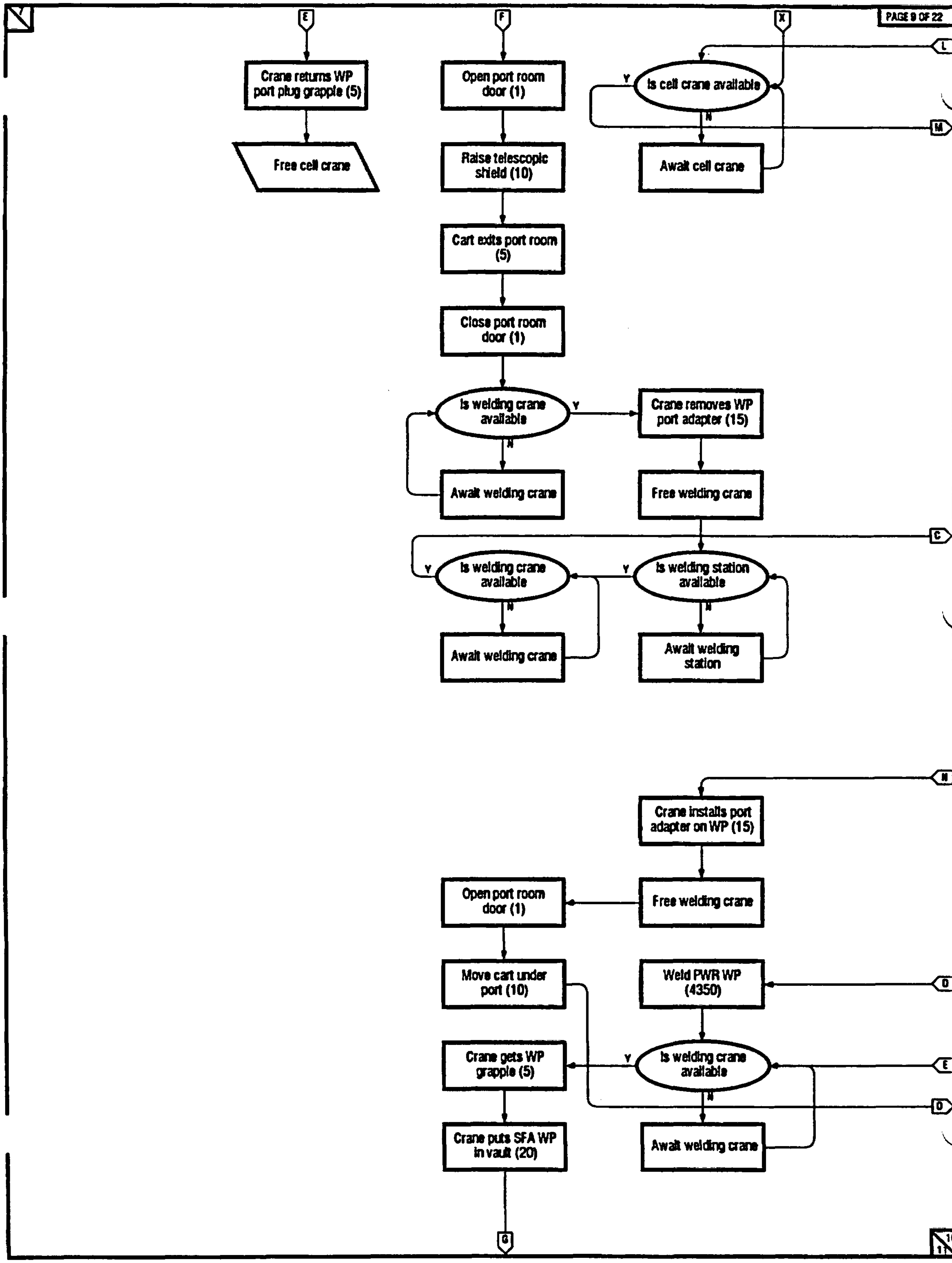

U
M
L
N
Crane takes lid to lay down (15)
Await cell crane
Crane puts lid on cask (15)
Crane returns lid grapple (5)
Crane returns lid grapple (5)
Crane gets MPC grapple (5)
Crane gets port plug grapple (5)
Crane puts MPC in lag (20)
Crane puts plug on port (10)
Crane returns MPC grapple (5)
Crane returns plug grapple (5)
Free cell crane
Free cell crane
Inspect cask lid for contamination (15)
Parallel operations
Inspection normal?
Y,75
N
On cask
On HLWC
Is empty HLWC WP in vault
Y
N
Go to UNLOADED CASK OPERATIONS
Lag has HLWC WP worth of HLWC
Y
N
Await empty HLWC WP in vault
Is cell WP port available
Y
N
Await HLWC WP worth of HLWC in lag
Crane gets WP grapple (5)
Await cell WP port
Is welding crane available
Y
N
Crane puts empty HLWC WP on WP cart (20)
Take corrective action (60)
Await welding crane
Crane returns WP grapple (5)
Is cell crane available
N
Y
Await cell crane
Crane installs port adapter on WP (15)
Free welding crane
Crane gets cask lid grapple (5)
O
V

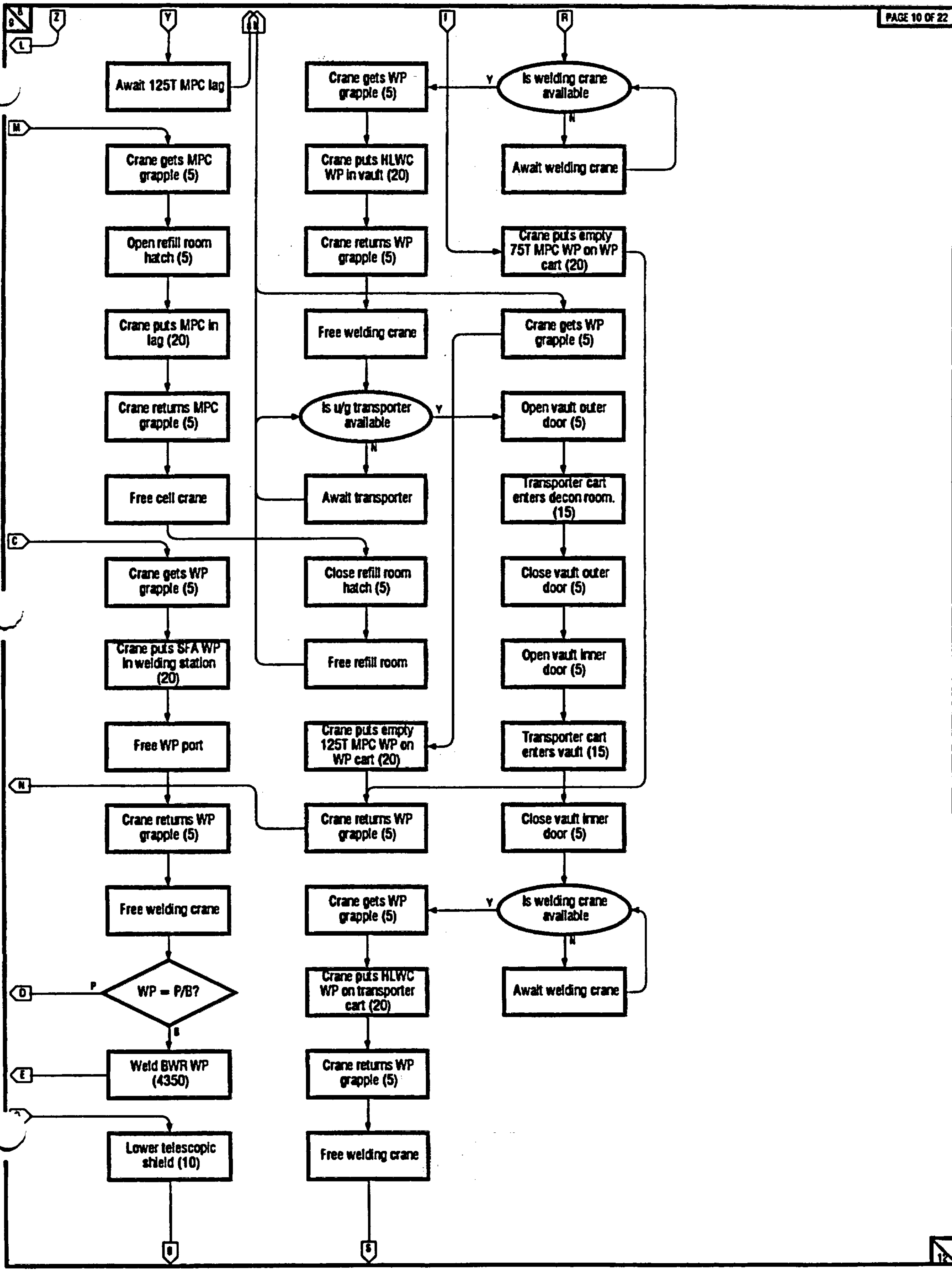

B
C
Go to UNLOADED CASK OPERATIONS
SFA = P/B?
P
Lag has PWR WP worth of SFA
Y
N
Await PWR WP worth of SFA in lag
B
Lag has BWR WP worth of SFA
N
Await BWR WP worth of SFA in lag
Y
Is empty BWR WP in vault
N
Await empty BWR WP in vault
Y
B
Is cell WP port available
N
Await cell WP port
Y
Is welding crane available
N
Await welding crane
Y
WP needed = P/B?
P
Crane gets WP grapple (5)
Crane puts empty PWR WP on WP cart (20)
B
Crane gets WP grapple (5)
Crane puts empty BWR WP on WP cart (20)
H
On cask
Go to UNLOADED CASK OPERATIONS
Crane returns WP grapple (5)
Crane installs port adapter on WP (15)
Free welding crane
Open port room door (1)
Move cart under port (10)
Lower telescopic shield (10)
D
3
8
7

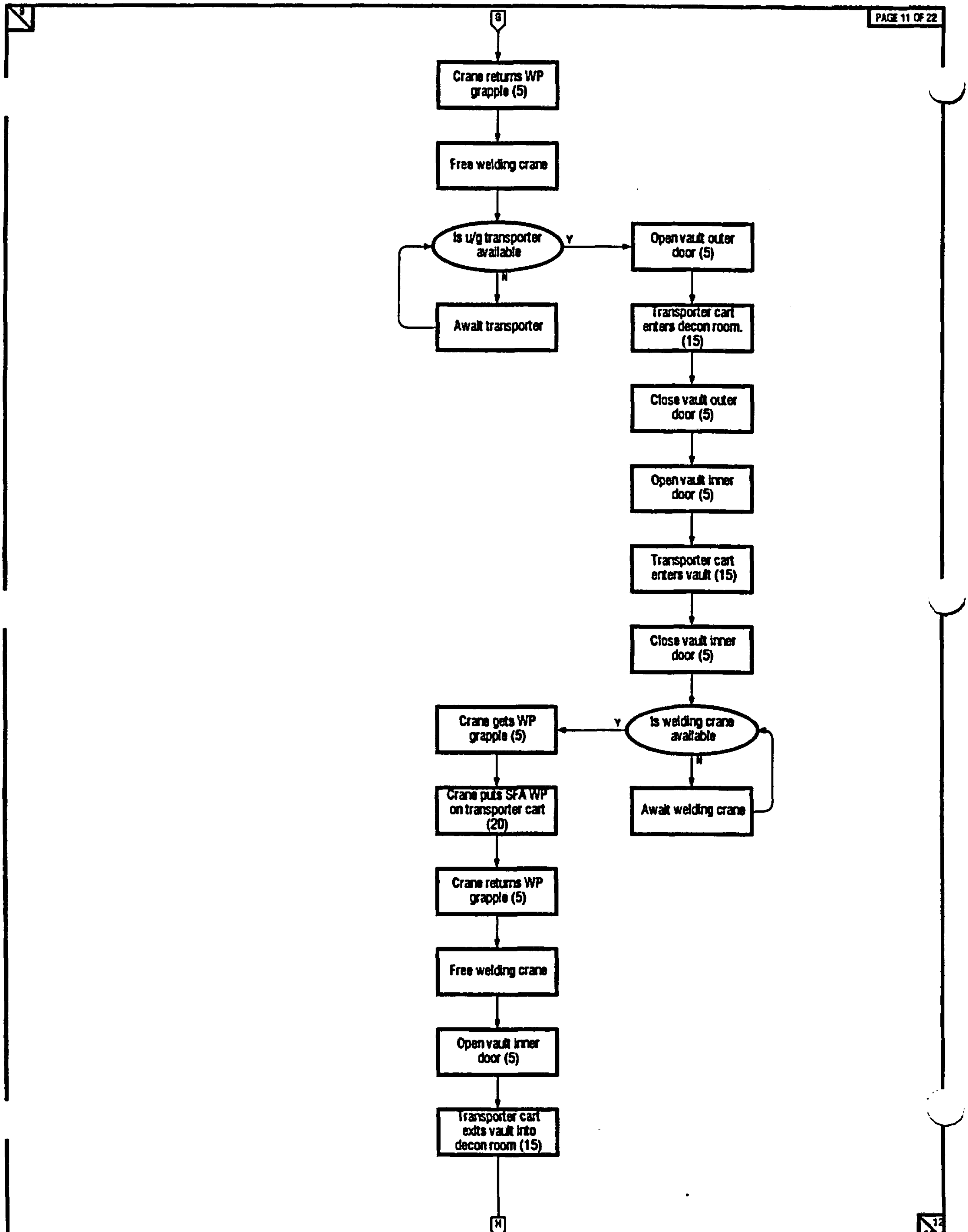

Is empty PWR WP in vault
Await empty PWR WP in vault
Open port room door (1)
Move cart under port (10)
Lower telescopic shield (10)
Close port room door (1)
Is cell crane available
Await cell crane
Crane puts lid on cask (15)
Crane returns lid grapple (5)
Crane gets port plug grapple (5)
Crane puts plug on port (10)
Crane gets WP port plug grapple (5)
Crane takes WP port plug to lay down (10)
Crane returns WP port plug grapple (5)
Crane gets HLWC grapple (5)
Crane returns plug grapple (5)
Free cell crane
Parallel operations
On MPC
Refill MPC?
MPC = 75T/125T?
75T
125T
Is there space in WP
Crane puts one HLWC from lag into WP (20)
Free HLWC WP worth of lag space
Crane returns HLWC grapple (5)
Crane gets WP port plug grapple (5)
Crane puts WP port plug on port (10)
Parallel operations
On WP
Is refill room available
Await refill room
Is cell crane available
Await cell crane
On crane
Is empty 75T MPC WP in vault
Await empty 75T MPC WP in vault
Is empty 125T MPC WP in vault
Await empty 125T MPC WP in vault

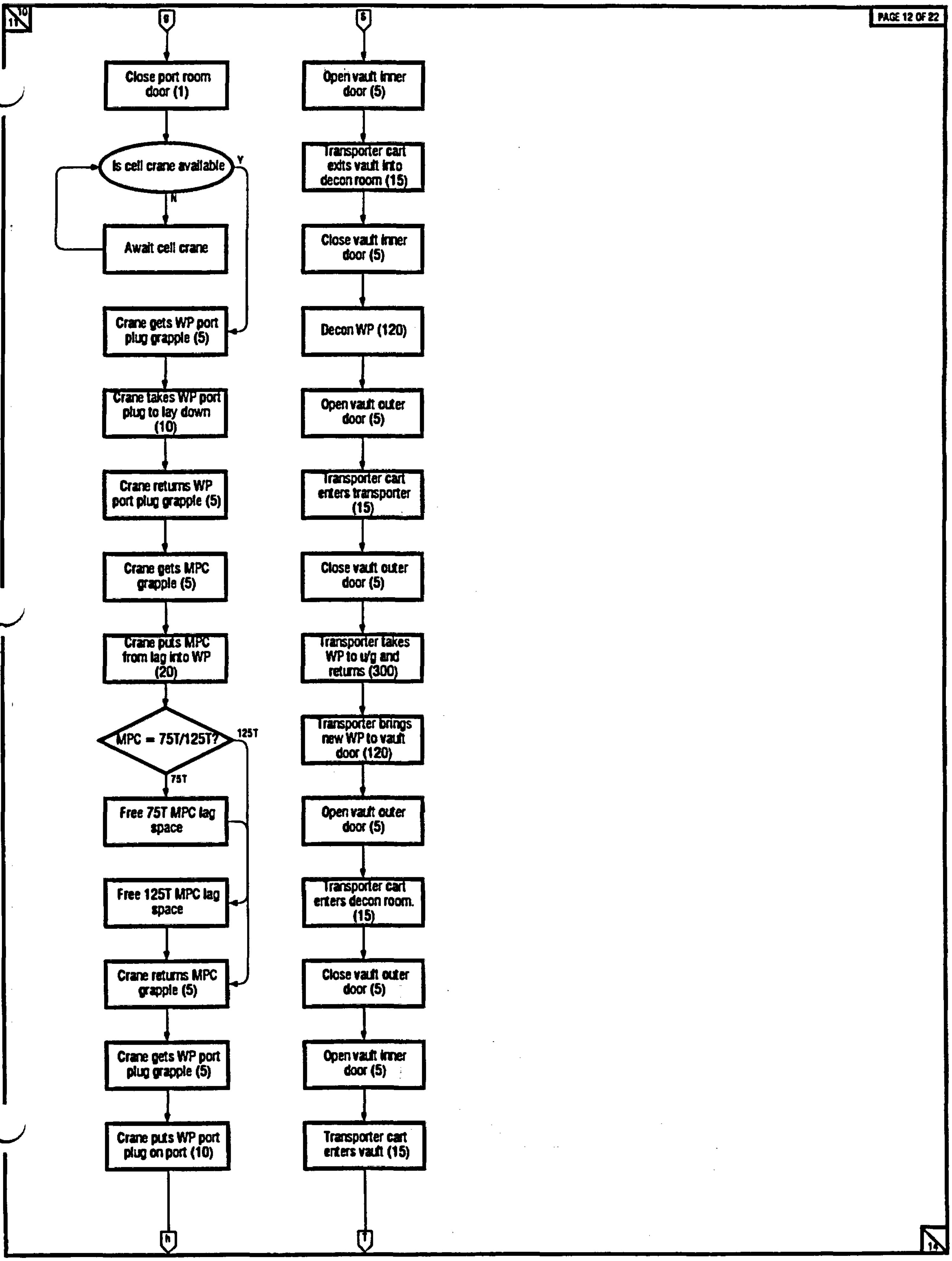

D
Close port room door (1)
Is cell crane available
N
Await cell crane
Y
Crane gets WP port plug grapple (5)
Crane takes WP port plug to lay down (10)
Crane returns WP port plug grapple (5)
Crane gets SFA grapple (5)
Is there space in WP
Y
Crane puts one SFA from lag into WP (20)
Free 75T MPC lag space
I
N
WP = P/B?
P
Free PWR WP worth of PWR lag space
J
B
Free BWR WP worth of BWR lag space
Crane returns SFA grapple (5)
Crane gets WP port plug grapple (5)
Open 75T MPC (180)
K
Crane puts WP port plug on port (10)
Refill and close 75T MPC (570)
Parallel operations
Is 75T MPC lag space available
Y
N
On crane
On WP
Await 75T MPC lag
E
F
X


P
W
Q
d
c
Crane returns WP port plug grapple (5)
Free cell crane
Crane gets MPC grapple (5)
Open refill room hatch (5)
Crane puts MPC in refill room (20)
Close refill room hatch (5)
MPC = 75T/125T?
75T
I
125T
Free 125T MPC lag space
J
Crane returns MPC grapple (5)
Free cell crane
MPC = 75T/125T?
75T
K
125T
Open 125T MPC (210)
Refill and close 125T MPC (702)
Is 125T MPC lag space available
Y
N
Z
V
Open port room door (1)
Raise telescopic shield (10)
Cart exits port room (5)
Close port room door (1)
Is welding crane available
Y
N
Await welding crane
Is welding crane available
Y
N
Await welding crane
Is cell WP port available
Y
N
Await cell WP port
Is welding crane available
Y
N
Await welding crane
WP needed = 75TP/125T?
125T
75T
Crane gets WP grapple (5)
Crane removes WP port adapter (15)
Free welding crane
Is welding station available
Y
N
Await welding station
Crane gets WP grapple (5)
Crane puts HLWC WP in welding station (20)
Free WP port
Crane returns WP grapple (5)
Free welding crane
Weld HLWC WP (4584)
R

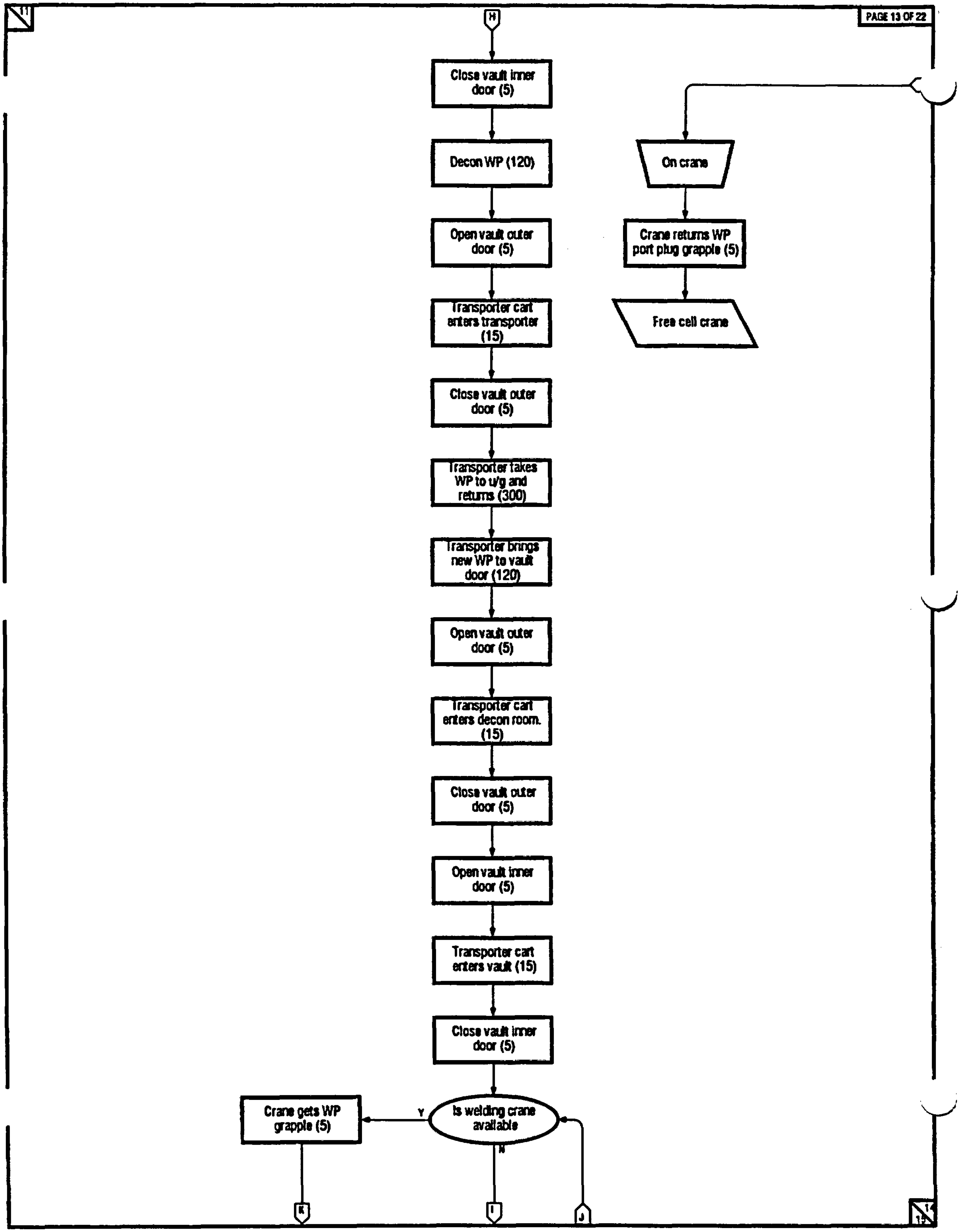

E
F
X
L
Crane returns WP port plug grapple (5)
Open port room door (1)
Is cell crane available
Y
N
M
Free cell crane
Raise telescopic shield (10)
Await cell crane
Cart exits port room (5)
Close port room door (1)
Is welding crane available
Y
N
Crane removes WP port adapter (15)
Await welding crane
Free welding crane
C
Is welding crane available
Y
N
Is welding station available
Y
N
Await welding crane
Await welding station
N
Crane installs port adapter on WP (15)
Open port room door (1)
Free welding crane
Move cart under port (10)
Weld PWR WP (4350)
D
Crane gets WP grapple (5)
Is welding crane available
Y
N
E
D
Crane puts SFA WP in vault (20)
Await welding crane
G

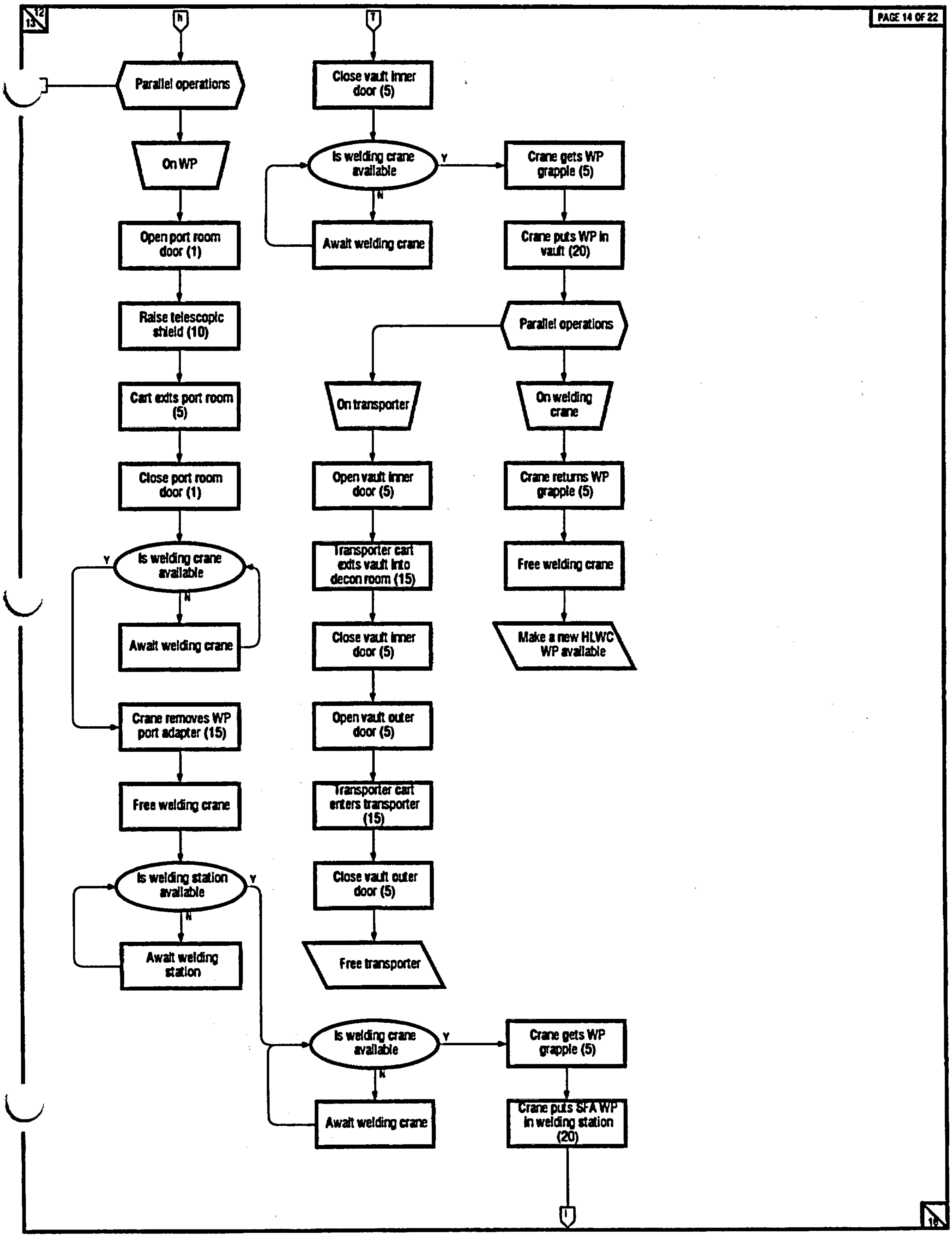

Z
Y
I
R
L
Await 125T MPC lag
Crane gets WP grapple (5)
Y
Is welding crane available
N
Await welding crane
M
Crane gets MPC grapple (5)
Crane puts HLWC WP in vault (20)
Open refill room hatch (5)
Crane returns WP grapple (5)
Crane puts empty 75T MPC WP on WP cart (20)
Crane puts MPC in lag (20)
Free welding crane
Crane gets WP grapple (5)
Crane returns MPC grapple (5)
Is u/g transporter available
Y
N
Open vault outer door (5)
Free cell crane
Await transporter
Transporter cart enters decon room. (15)
C
Crane gets WP grapple (5)
Close refill room hatch (5)
Close vault outer door (5)
Crane puts SFA WP in welding station (20)
Free refill room
Open vault inner door (5)
Free WP port
Crane puts empty 125T MPC WP on WP cart (20)
Transporter cart enters vault (15)
N
Crane returns WP grapple (5)
Crane returns WP grapple (5)
Close vault inner door (5)
Free welding crane
Crane gets WP grapple (5)
Y
Is welding crane available
N
D
P
WP = P/B?
Crane puts HLWC WP on transporter cart (20)
Await welding crane
B
E
Weld BWR WP (4350)
Crane returns WP grapple (5)
Lower telescopic shield (10)
Free welding crane

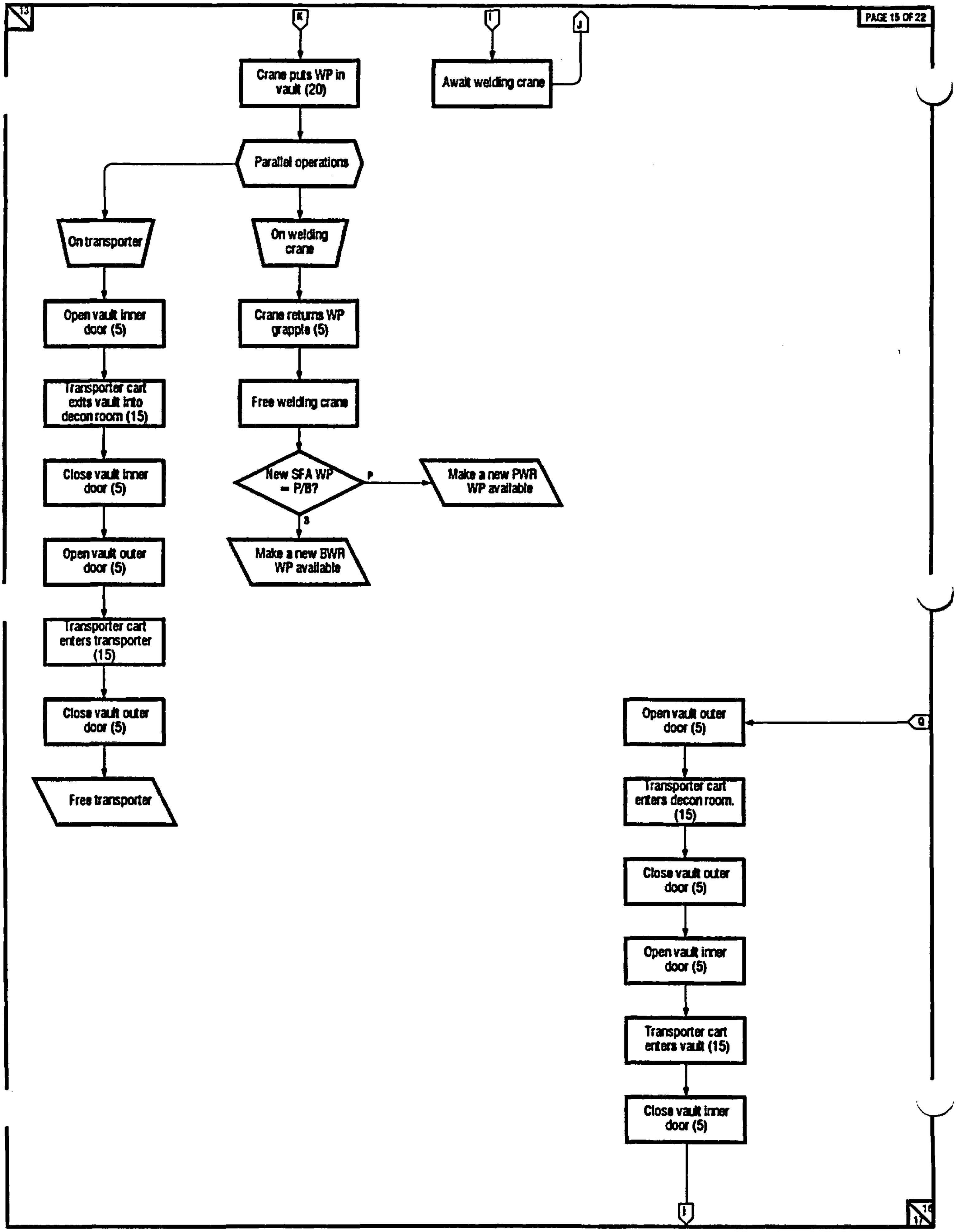

G
Crane returns WP grapple (5)
Free welding crane
Is u/g transporter available
Y
N
Await transporter
Open vault outer door (5)
Transporter cart enters decon room. (15)
Close vault outer door (5)
Open vault inner door (5)
Transporter cart enters vault (15)
Close vault inner door (5)
Is welding crane available
Y
N
Await welding crane
Crane gets WP grapple (5)
Crane puts SFA WP on transporter cart (20)
Crane returns WP grapple (5)
Free welding crane
Open vault inner door (5)
Transporter cart exits vault into decon room (15)
H

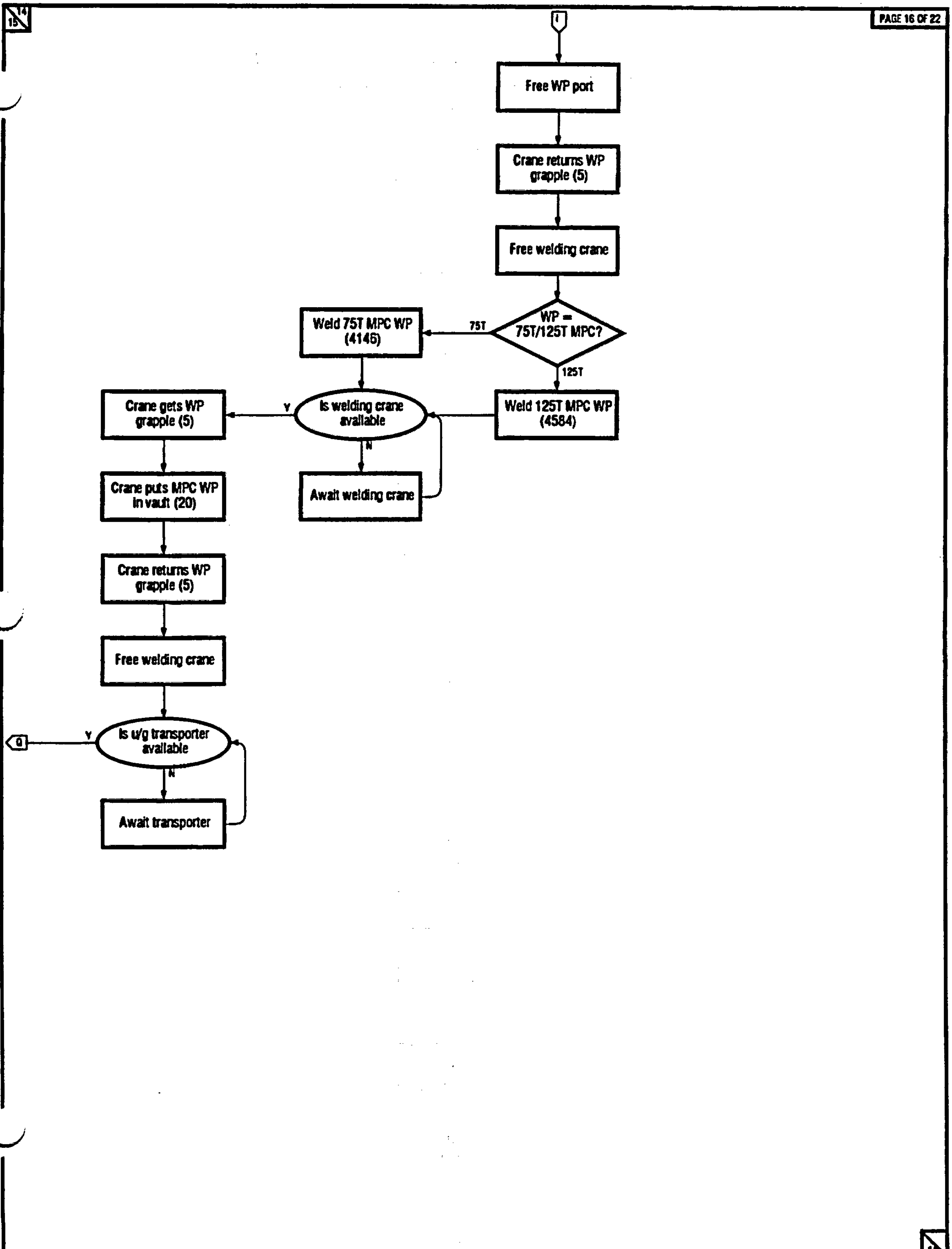


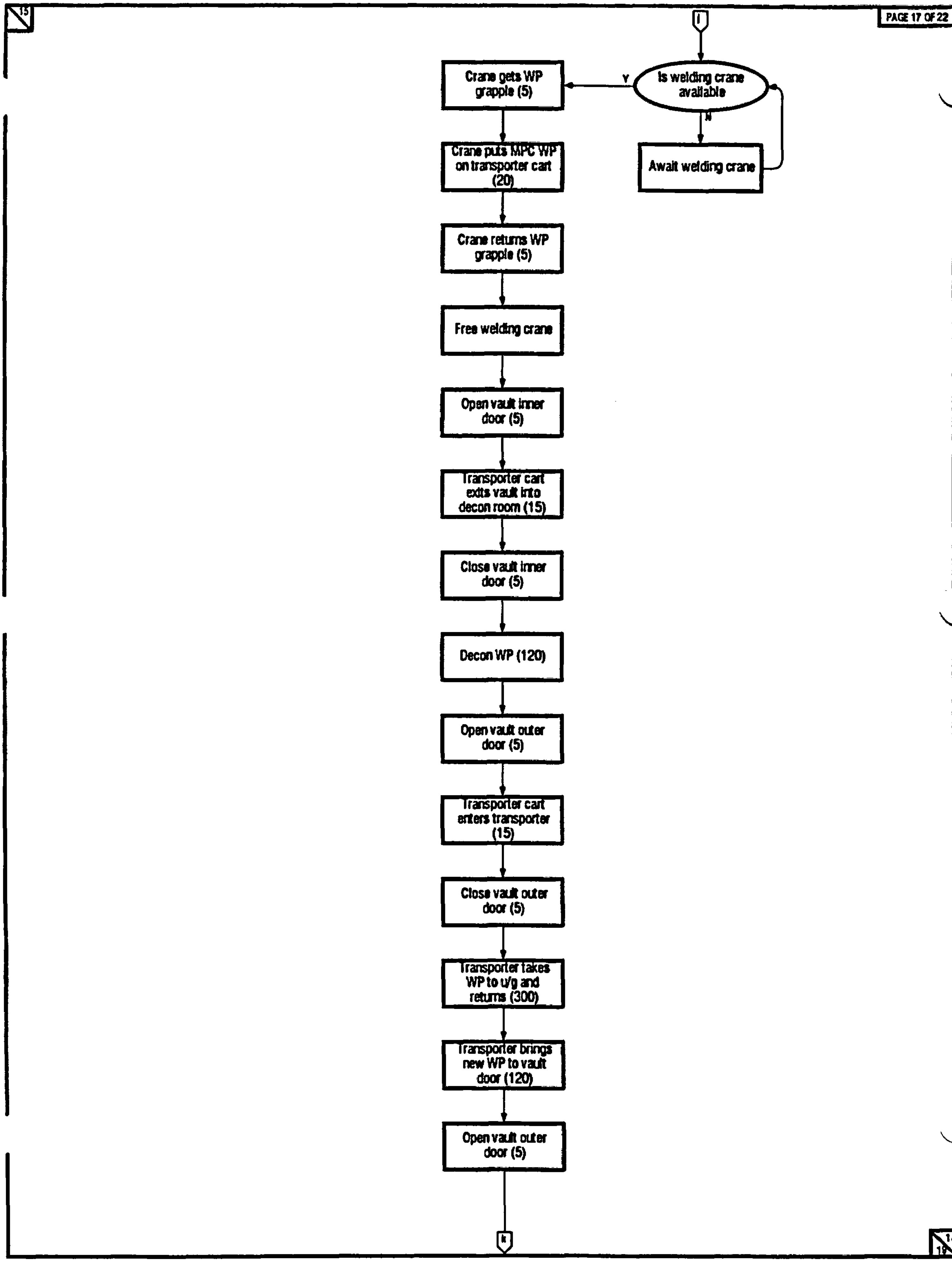
Close port room door (1)
Is cell crane available
Y
N
Await cell crane
Crane gets WP port plug grapple (5)
Crane takes WP port plug to lay down (10)
Crane returns WP port plug grapple (5)
Crane gets MPC grapple (5)
Crane puts MPC from lag into WP (20)
MPC = 75T/125T?
125T
75T
Free 75T MPC lag space
Free 125T MPC lag space
Crane returns MPC grapple (5)
Crane gets WP port plug grapple (5)
Crane puts WP port plug on port (10)
Open vault inner door (5)
Transporter cart exits vault into decon room (15)
Close vault inner door (5)
Decon WP (120)
Open vault outer door (5)
Transporter cart enters transporter (15)
Close vault outer door (5)
Transporter takes WP to u/g and returns (300)
Transporter brings new WP to vault door (120)
Open vault outer door (5)
Transporter cart enters decon room. (15)
Close vault outer door (5)
Open vault inner door (5)
Transporter cart enters vault (15)

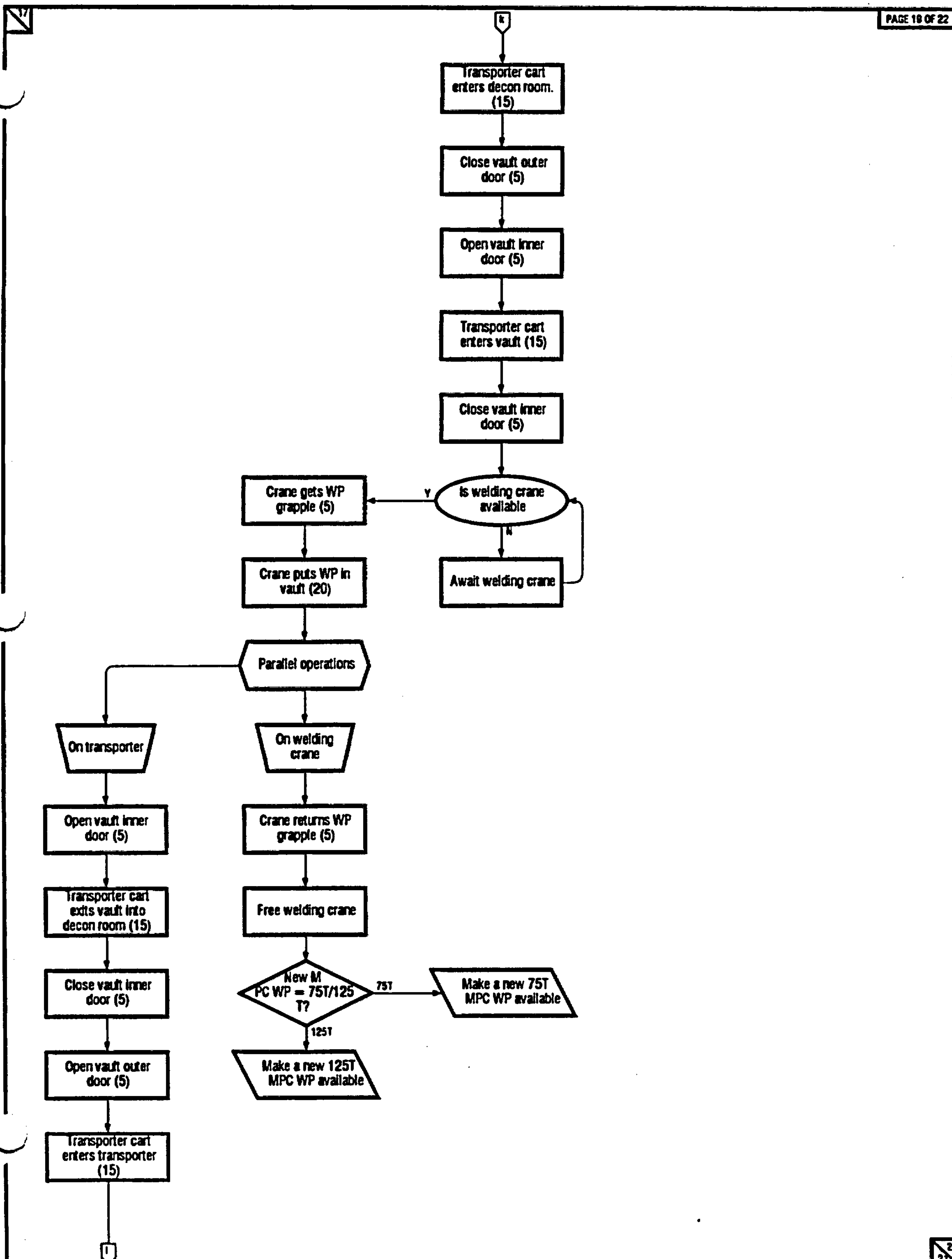

H
Close vault inner door (5)
Decon WP (120)
Open vault outer door (5)
Transporter cart enters transporter (15)
Close vault outer door (5)
Transporter takes WP to u/g and returns (300)
Transporter brings new WP to vault door (120)
Open vault outer door (5)
Transporter cart enters decon room. (15)
Close vault outer door (5)
Open vault inner door (5)
Transporter cart enters vault (15)
Close vault inner door (5)
Is welding crane available
Y
N
Crane gets WP grapple (5)
K
I
J
On crane
Crane returns WP port plug grapple (5)
Free cell crane
11
14
15

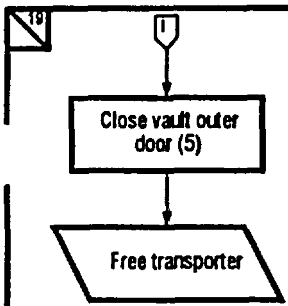

12
13
h
T
Parallel operations
On WP
Open port room door (1)
Raise telescopic shield (10)
Cart exits port room (5)
Close port room door (1)
Is welding crane available
Y
N
Await welding crane
Crane removes WP port adapter (15)
Free welding crane
Is welding station available
Y
N
Await welding station
Close vault inner door (5)
Is welding crane available
Y
N
Await welding crane
Crane gets WP grapple (5)
Crane puts WP in vault (20)
Parallel operations
On transporter
Open vault inner door (5)
Transporter cart exits vault into decon room (15)
Close vault inner door (5)
Open vault outer door (5)
Transporter cart enters transporter (15)
Close vault outer door (5)
Free transporter
On welding crane
Crane returns WP grapple (5)
Free welding crane
Make a new HLWC WP available
Is welding crane available
Y
N
Await welding crane
Crane gets WP grapple (5)
Crane puts SFA WP in welding station (20)
I
16


13
K
I
J
Crane puts WP in vault (20)
Await welding crane
Parallel operations
On transporter
On welding crane
Open vault inner door (5)
Crane returns WP grapple (5)
Transporter cart exits vault into decon room (15)
Free welding crane
Close vault inner door (5)
New SFA WP = P/B?
P
Make a new PWR WP available
B
Open vault outer door (5)
Make a new BWR WP available
Transporter cart enters transporter (15)
Close vault outer door (5)
Free transporter
Open vault outer door (5)
Q
Transporter cart enters decon room. (15)
Close vault outer door (5)
Open vault inner door (5)
Transporter cart enters vault (15)
Close vault inner door (5)
I
16
17

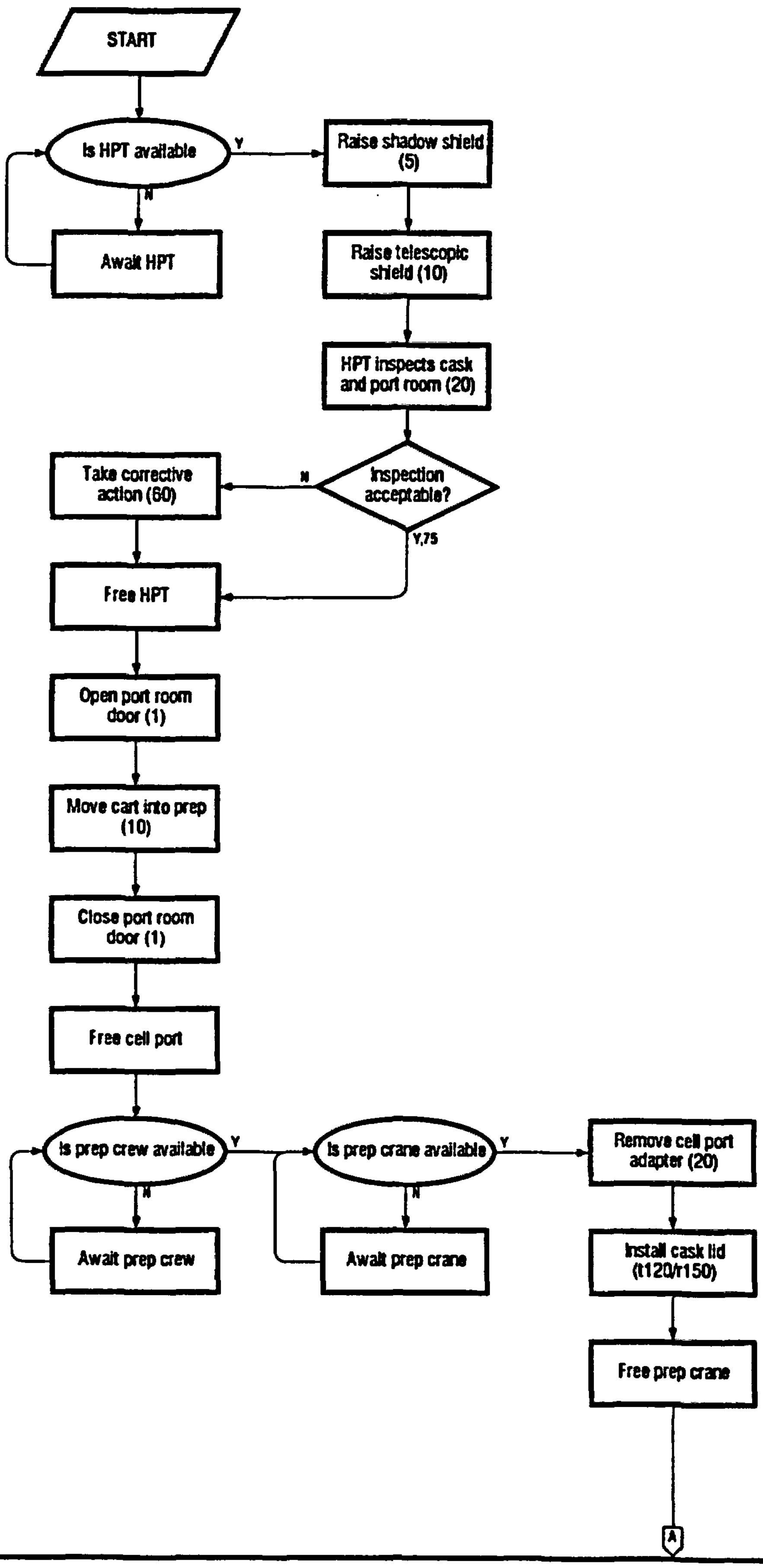

14
15
I
Free WP port
Crane returns WP grapple (5)
Free welding crane
WP = 75T/125T MPC?
75T
125T
Weld 75T MPC WP (4146)
Weld 125T MPC WP (4584)
Is welding crane available
Y
N
Await welding crane
Crane gets WP grapple (5)
Crane puts MPC WP in vault (20)
Crane returns WP grapple (5)
Free welding crane
Is u/g transporter available
Y
N
Q
Await transporter
16

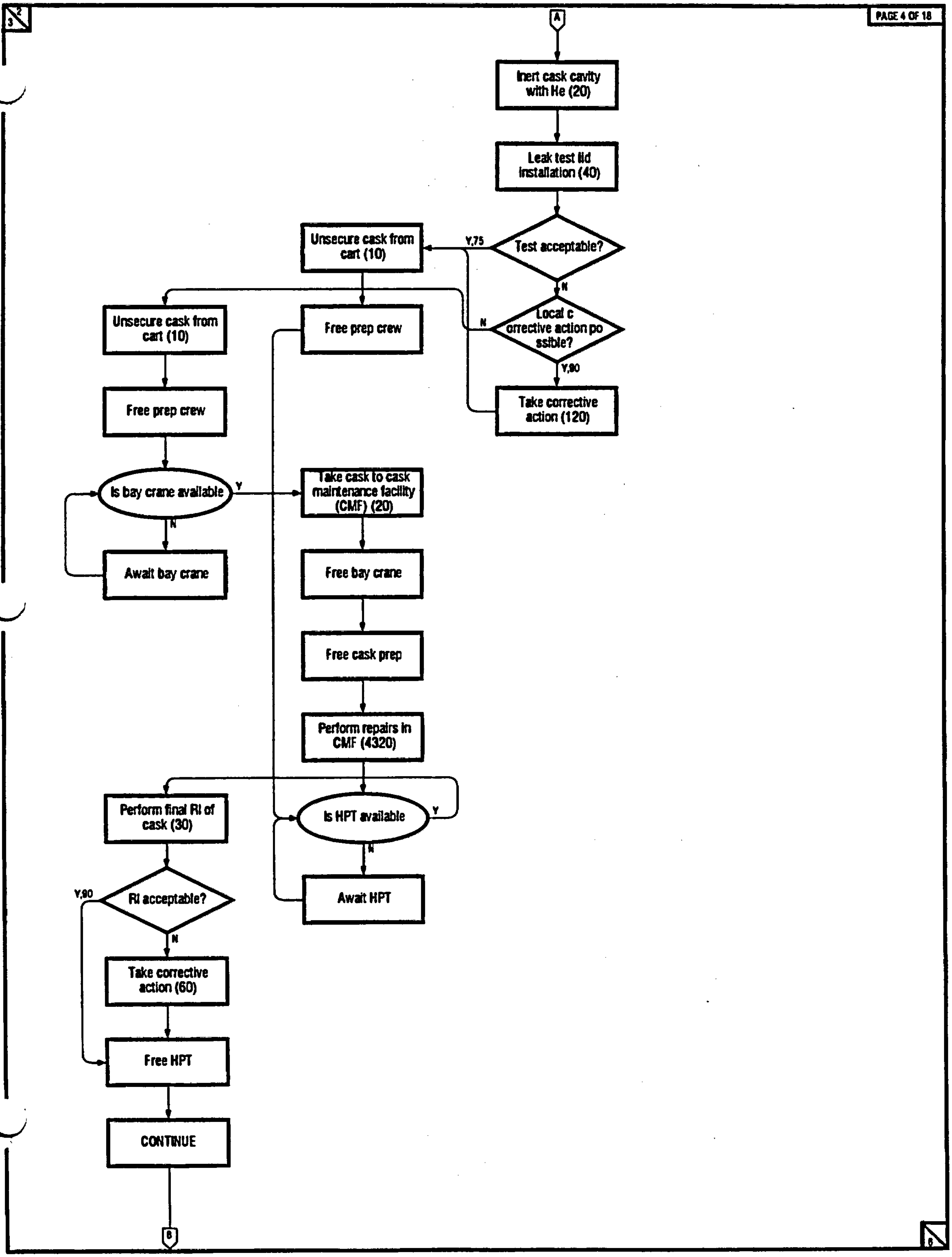

15
i
Is welding crane available
Y
N
Await welding crane
Crane gets WP grapple (5)
Crane puts MPC WP on transporter cart (20)
Crane returns WP grapple (5)
Free welding crane
Open vault inner door (5)
Transporter cart exits vault into decon room (15)
Close vault inner door (5)
Decon WP (120)
Open vault outer door (5)
Transporter cart enters transporter (15)
Close vault outer door (5)
Transporter takes WP to u/g and returns (300)
Transporter brings new WP to vault door (120)
Open vault outer door (5)
k
18
19

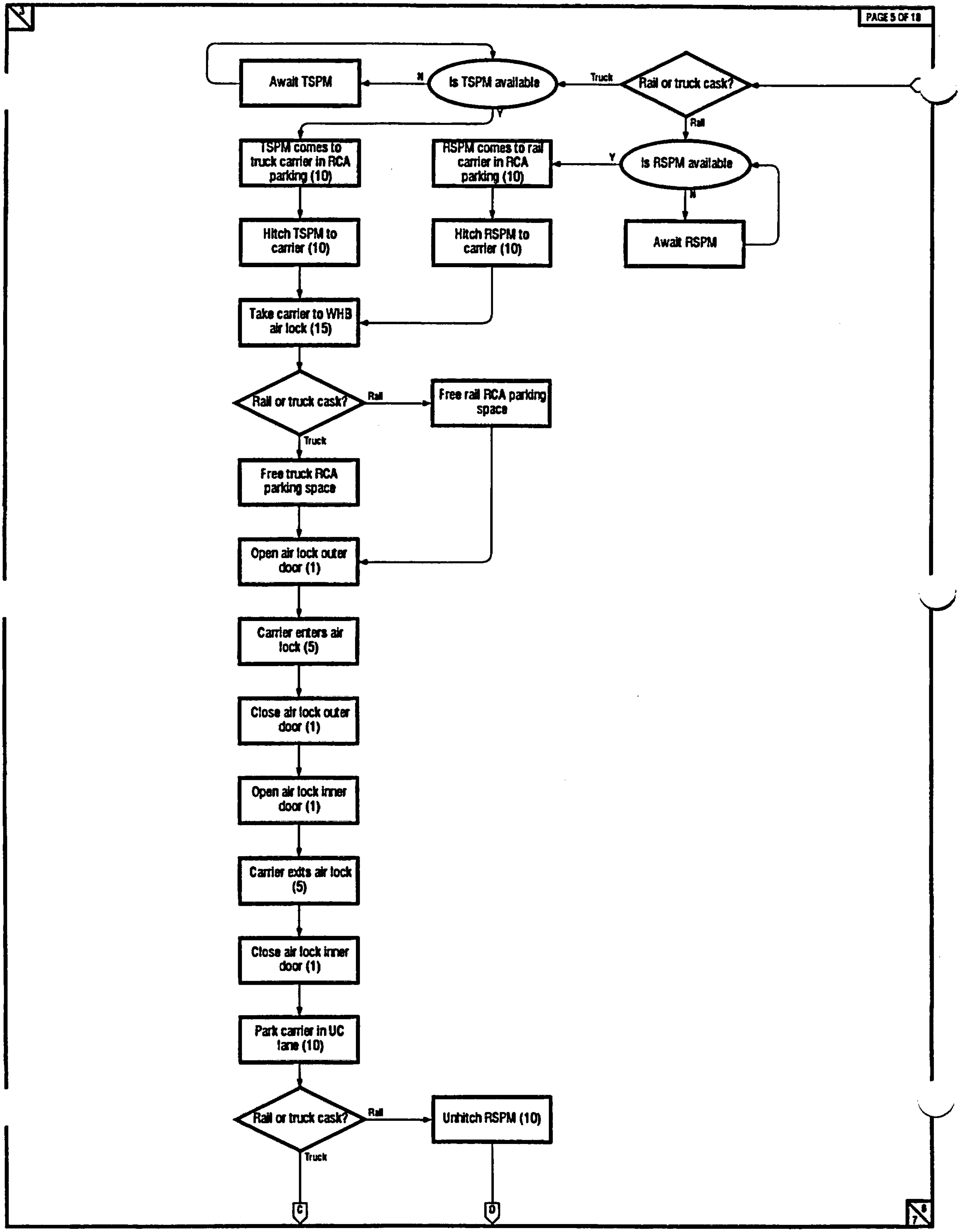

17
k
Transporter cart enters decon room. (15)
Close vault outer door (5)
Open vault inner door (5)
Transporter cart enters vault (15)
Close vault inner door (5)
Is welding crane available
Y
N
Crane gets WP grapple (5)
Await welding crane
Crane puts WP in vault (20)
Parallel operations
On transporter
On welding crane
Open vault inner door (5)
Crane returns WP grapple (5)
Transporter cart exits vault into decon room (15)
Free welding crane
Close vault inner door (5)
New MPC WP = 75T/125T?
75T
125T
Make a new 75T MPC WP available
Open vault outer door (5)
Make a new 125T MPC WP available
Transporter cart enters transporter (15)
l
20
21


19
I
Close vault outer door (5)
Free transporter

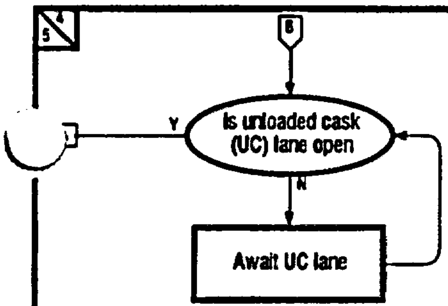
Unloaded Cask Operations

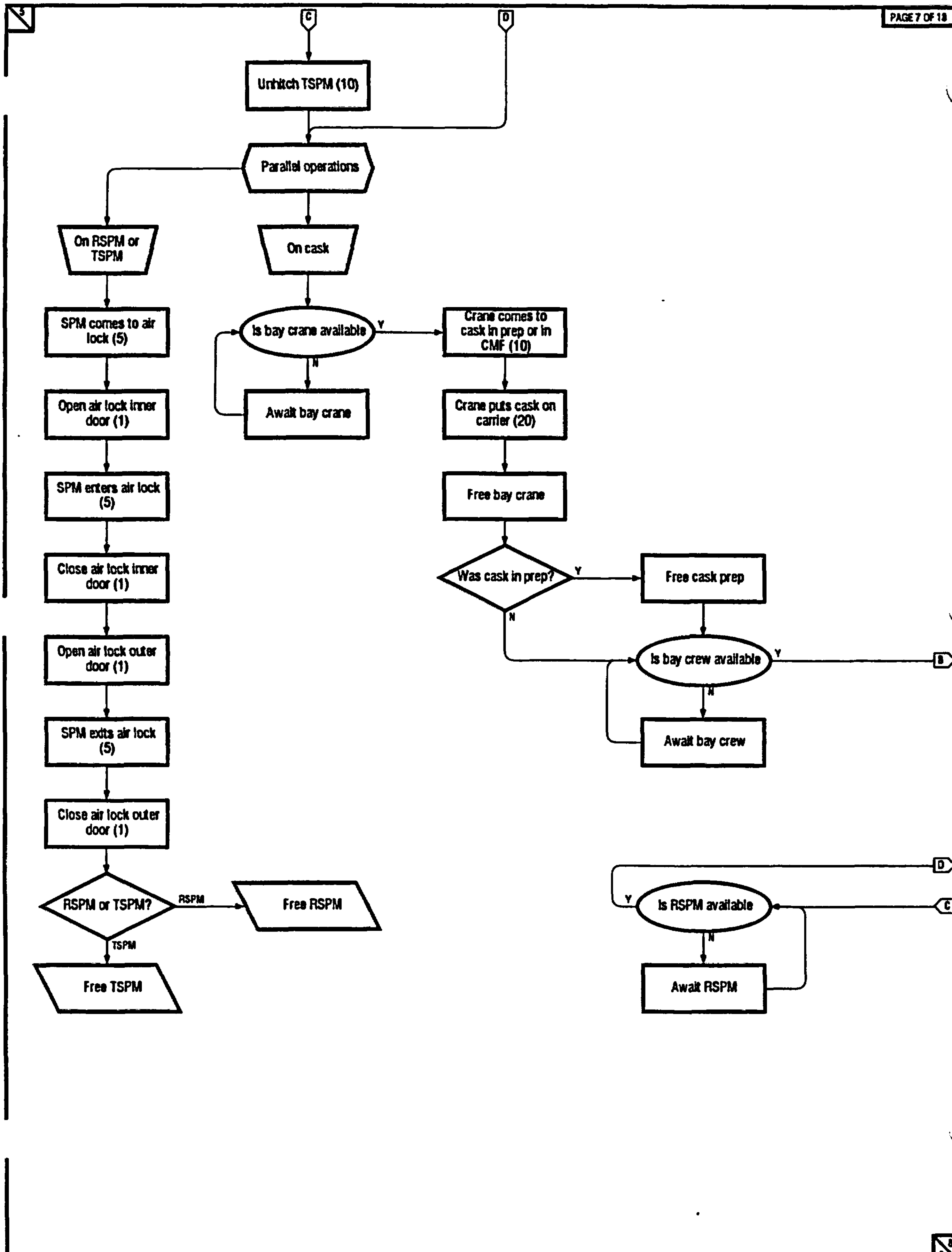

START
Is HPT available
Y
N
Await HPT
Raise shadow shield (5)
Raise telescopic shield (10)
HPT inspects cask and port room (20)
Inspection acceptable?
N
Y,75
Take corrective action (60)
Free HPT
Open port room door (1)
Move cart into prep (10)
Close port room door (1)
Free cell port
Is prep crew available
Y
N
Await prep crew
Is prep crane available
Y
N
Await prep crane
Remove cell port adapter (20)
Install cask lid (t120/r150)
Free prep crane
A

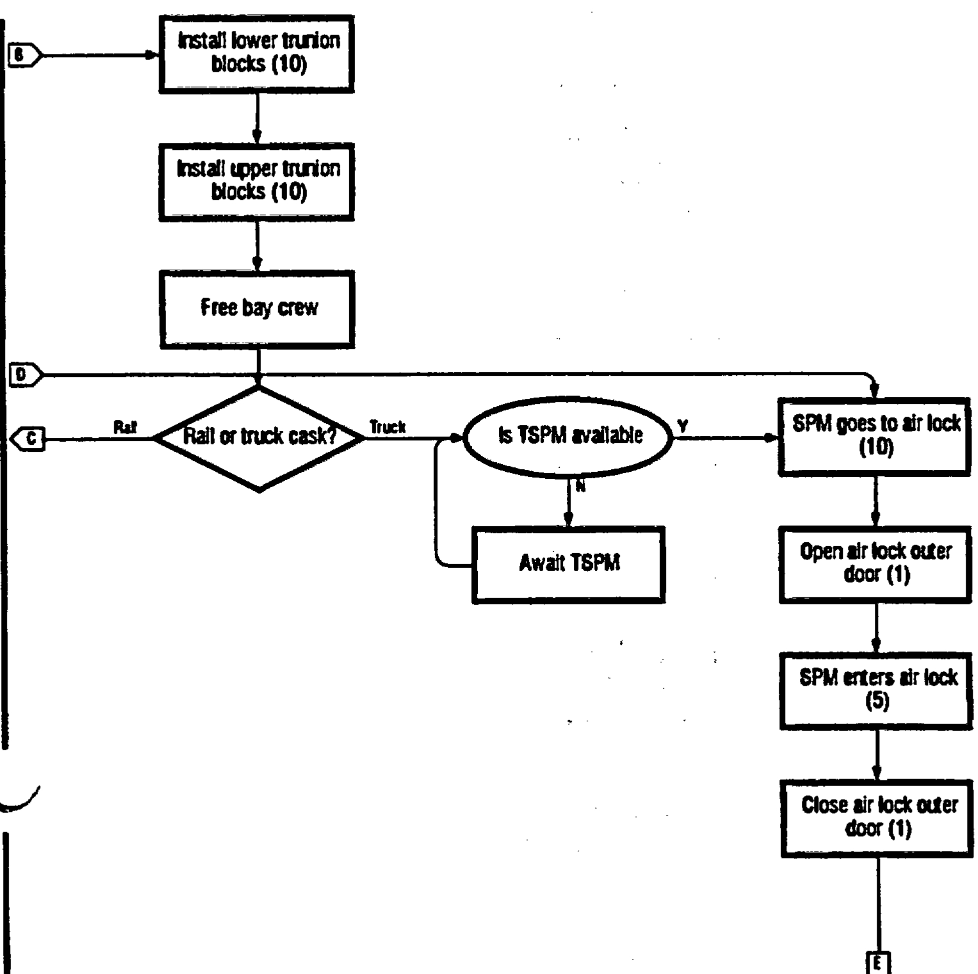

A
Inert cask cavity with He (20)
Leak test lid installation (40)
Test acceptable?
Y,75
N
Unsecure cask from cart (10)
Local c orrective action po ssible?
N
Y,90
Take corrective action (120)
Free prep crew
Unsecure cask from cart (10)
Free prep crew
Is bay crane available
Y
N
Await bay crane
Take cask to cask maintenance facility (CMF) (20)
Free bay crane
Free cask prep
Perform repairs in CMF (4320)
Is HPT available
Y
N
Await HPT
Perform final RI of cask (30)
RI acceptable?
Y,90
N
Take corrective action (60)
Free HPT
CONTINUE
B

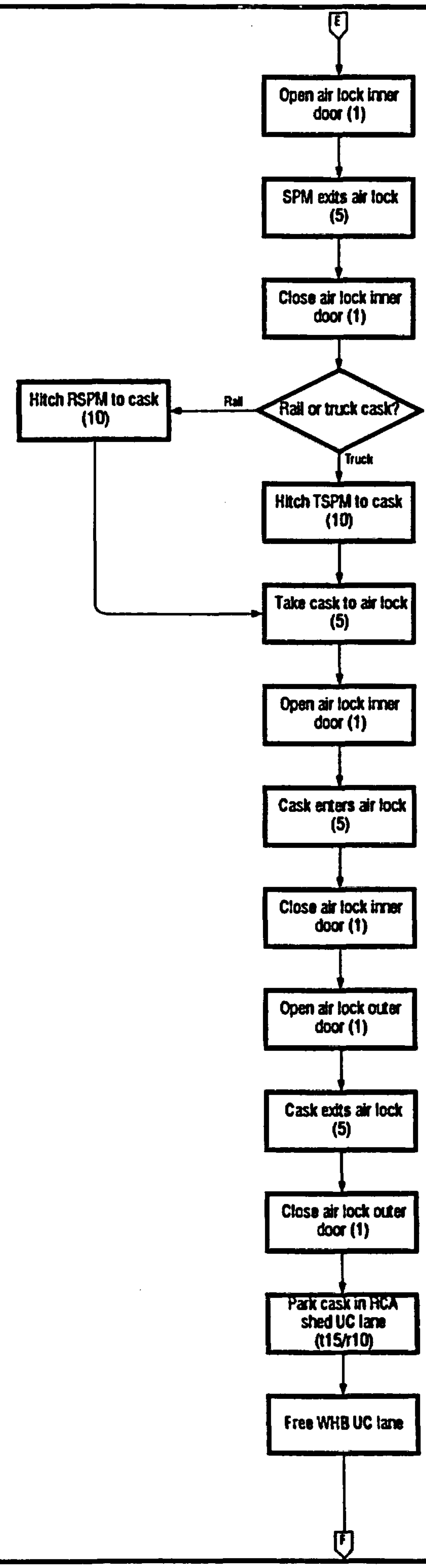


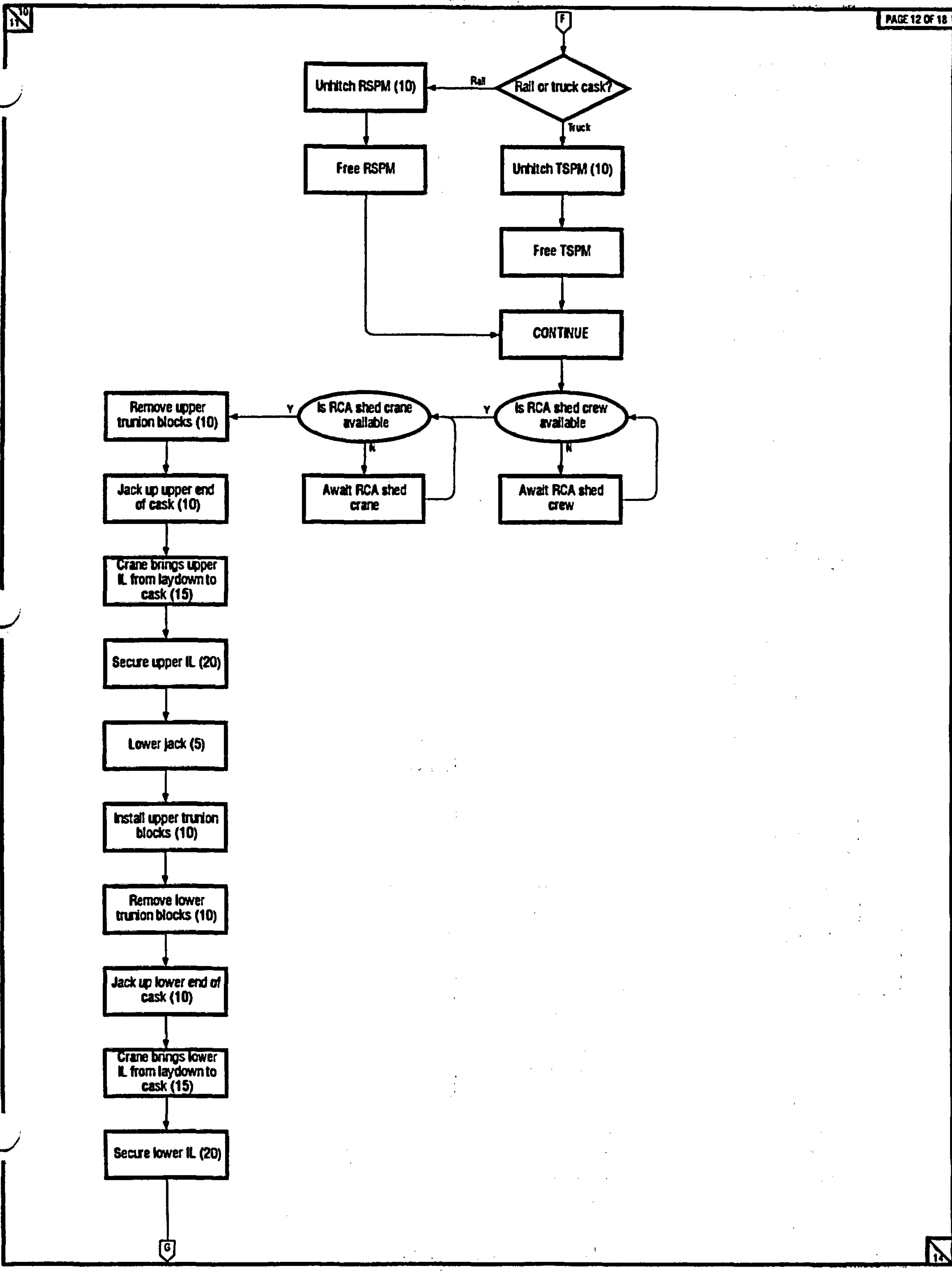
Rail or truck cask?
Truck
Rail
Is TSPM available
N
Y
Await TSPM
TSPM comes to truck carrier in RCA parking (10)
Is RSPM available
Y
N
RSPM comes to rail carrier in RCA parking (10)
Await RSPM
Hitch TSPM to carrier (10)
Hitch RSPM to carrier (10)
Take carrier to WHB air lock (15)
Rail or truck cask?
Rail
Truck
Free rail RCA parking space
Free truck RCA parking space
Open air lock outer door (1)
Carrier enters air lock (5)
Close air lock outer door (1)
Open air lock inner door (1)
Carrier exits air lock (5)
Close air lock inner door (1)
Park carrier in UC lane (10)
Rail or truck cask?
Rail
Truck
Unhitch RSPM (10)
C
D

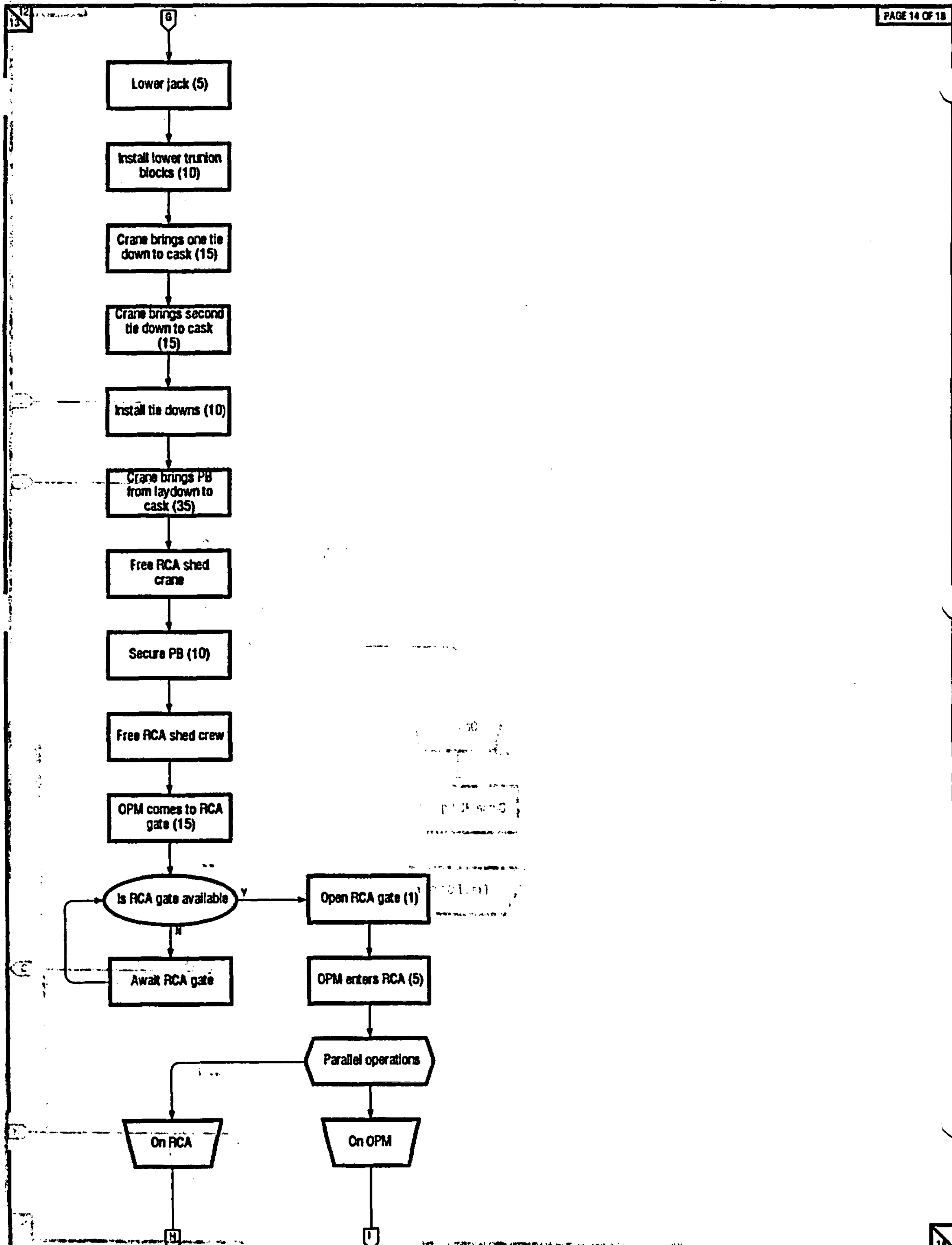

B
Y
Is unloaded cask
(UC) lane open
N
Await UC lane

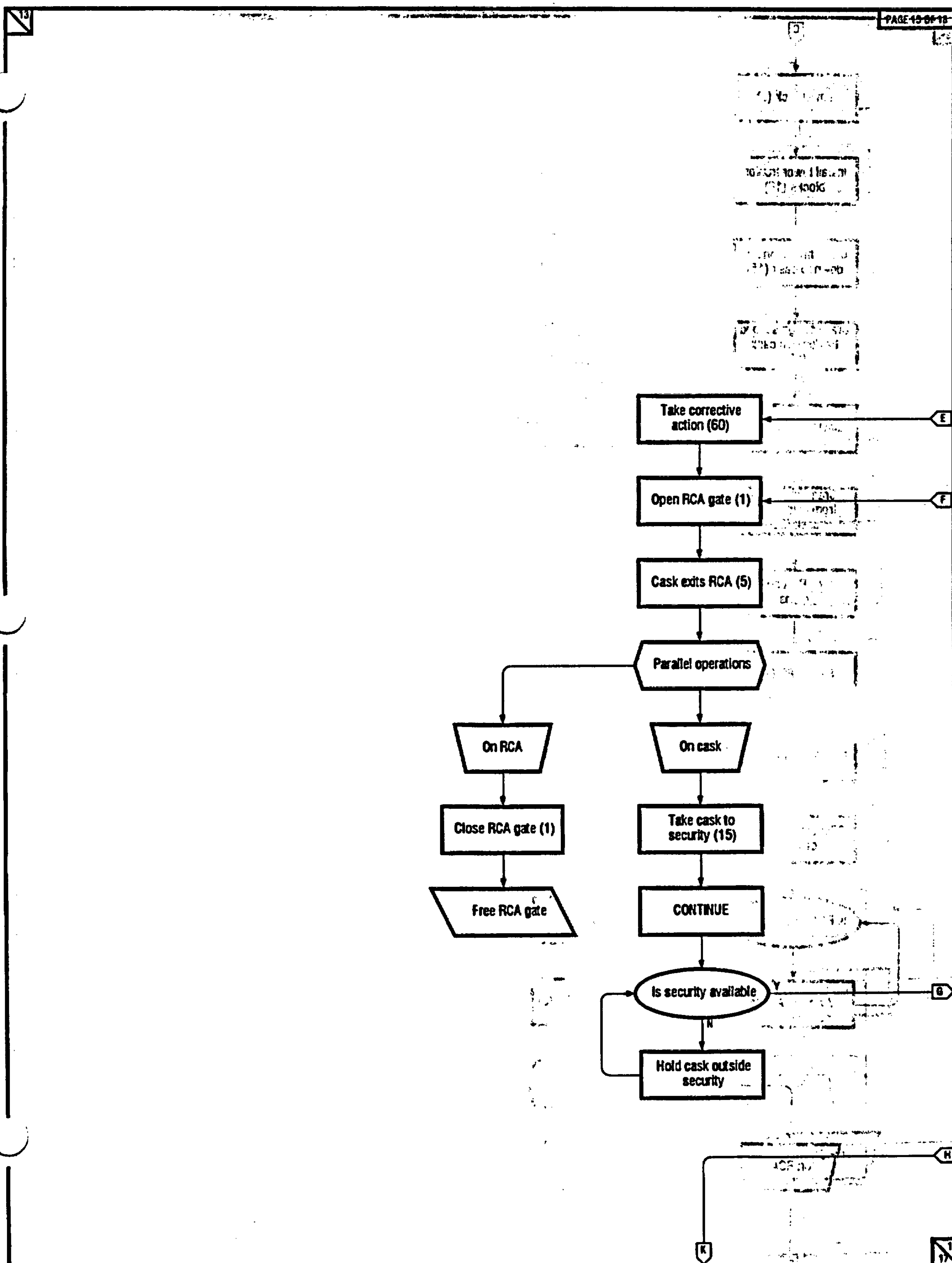

5
C
D
Unhitch TSPM (10)
Parallel operations
On RSPM or TSPM
On cask
SPM comes to air lock (5)
Is bay crane available
Y
N
Crane comes to cask in prep or in CMF (10)
Open air lock inner door (1)
Await bay crane
Crane puts cask on carrier (20)
SPM enters air lock (5)
Free bay crane
Close air lock inner door (1)
Was cask in prep?
Y
Free cask prep
N
Open air lock outer door (1)
Is bay crew available
Y
B
N
SPM exits air lock (5)
Await bay crew
Close air lock outer door (1)
D
RSPM or TSPM?
RSPM
Free RSPM
Y
Is RSPM available
C
TSPM
N
Free TSPM
Await RSPM
8
9


B
Install lower trunion blocks (10)
Install upper trunion blocks (10)
Free bay crew
D
C
Rail
Rail or truck cask?
Truck
Is TSPM available
Y
N
Await TSPM
SPM goes to air lock (10)
Open air lock outer door (1)
SPM enters air lock (5)
Close air lock outer door (1)
E

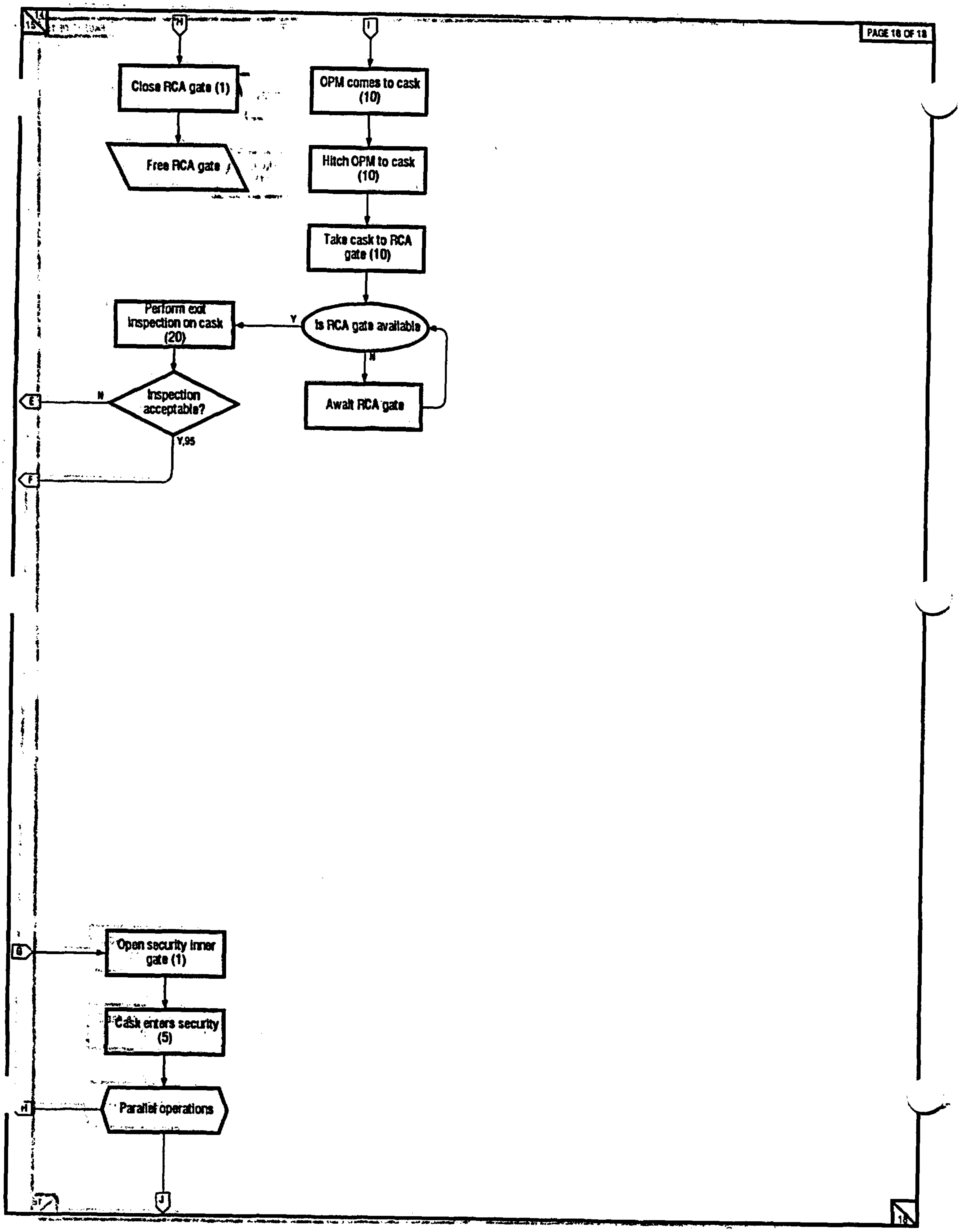

E
Open air lock inner door (1)
SPM exits air lock (5)
Close air lock inner door (1)
Rail or truck cask?
Rail
Hitch RSPM to cask (10)
Truck
Hitch TSPM to cask (10)
Take cask to air lock (5)
Open air lock inner door (1)
Cask enters air lock (5)
Close air lock inner door (1)
Open air lock outer door (1)
Cask exits air lock (5)
Close air lock outer door (1)
Park cask in RCA shed UC lane (t15/r10)
Free WHB UC lane
F

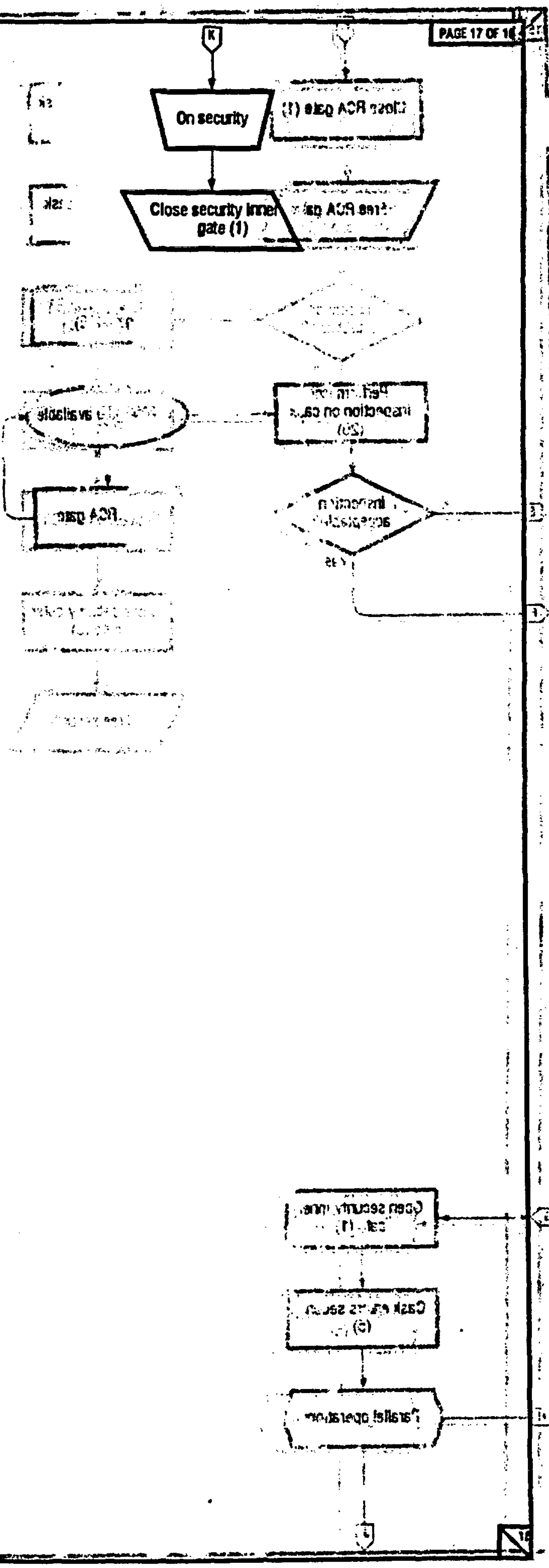

10
11
F
Rail or truck cask?
Rail
Unhitch RSPM (10)
Free RSPM
Truck
Unhitch TSPM (10)
Free TSPM
CONTINUE
Is RCA shed crew available
Y
N
Await RCA shed crew
Is RCA shed crane available
Y
N
Await RCA shed crane
Remove upper trunion blocks (10)
Jack up upper end of cask (10)
Crane brings upper IL from laydown to cask (15)
Secure upper IL (20)
Lower jack (5)
Install upper trunion blocks (10)
Remove lower trunion blocks (10)
Jack up lower end of cask (10)
Crane brings lower IL from laydown to cask (15)
Secure lower IL (20)
G
14

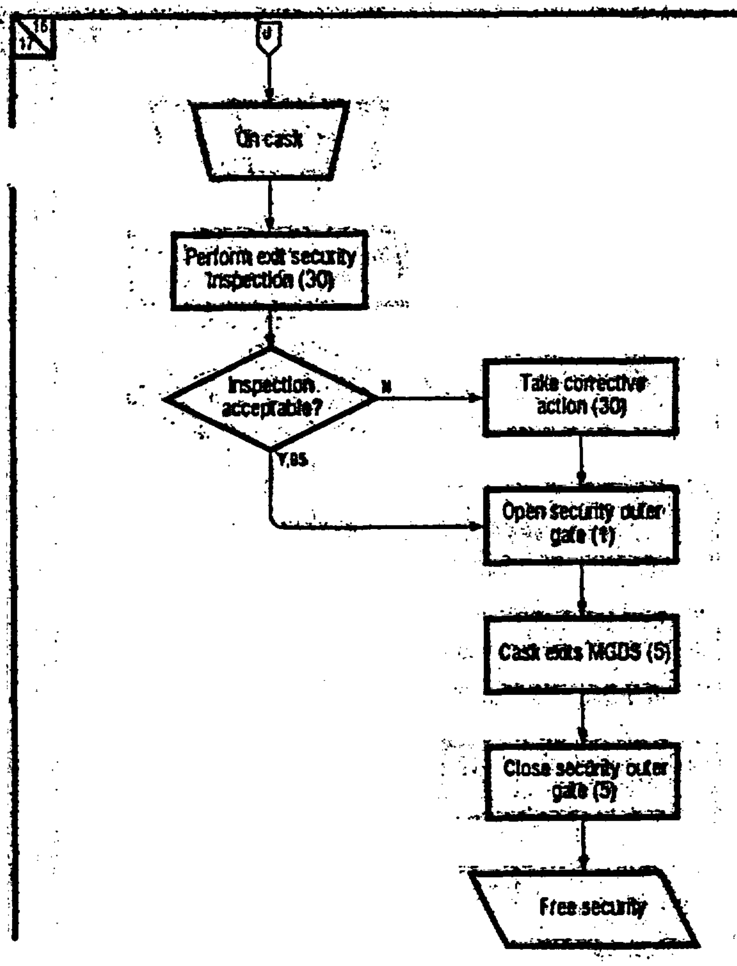

G
Lower jack (5)
Install lower trunion blocks (10)
Crane brings one tie down to cask (15)
Crane brings second tie down to cask (15)
Install tie downs (10)
Crane brings PB from laydown to cask (35)
Free RCA shed crane
Secure PB (10)
Free RCA shed crew
OPM comes to RCA gate (15)
Is RCA gate available
Y
N
Open RCA gate (1)
Await RCA gate
OPM enters RCA (5)
Parallel operations
On RCA
On OPM
H
I



13
Take corrective action (60)
E
Open RCA gate (1)
F
Cask exits RCA (5)
Parallel operations
On RCA
On cask
Close RCA gate (1)
Take cask to security (15)
Free RCA gate
CONTINUE
Is security available
Y
N
G
Hold cask outside security
H
K
16
17


H
I
Close RCA gate (1)
Free RCA gate
OPM comes to cask (10)
Hitch OPM to cask (10)
Take cask to RCA gate (10)
Is RCA gate available
Y
N
Await RCA gate
Perform exit inspection on cask (20)
Inspection acceptable?
N
E
Y,95
F
G
Open security inner gate (1)
Cask enters security (5)
H
Parallel operations
J


K
On security
Close security inner gate (1)


16
17
J
On cask
Perform exit security inspection (30)
Inspection acceptable?
N
YES
Take corrective action (30)
Open security outer gate (1)
Cask exits MGDS (5)
Close security outer gate (5)
Free security