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EXTENDING THE USEFUL LIFE OF DYE-2 TO 1986

PART II: 1979 FINDINGS AND FINAL RECOMMENDATIONS

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A major construction effort is needed at Dew Line Ice Cap Station DYE-2 to extend its useful life to 1986. That work should be done as soon as possible because the truss enclosure is deteriorating rapidly. Although a 210-ft sideways move as was accomplished at DYE-3 in 1977 is technically feasible, the alternative of backfilling the truss enclosure with ice is expected to cost about $2.7 million less. Unless there is a strong possibility that DYE-2 will be needed for many years beyond 1986, the ice backfill alternative is recommended.

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PREFACE

This report was prepared by Wayne Tobiasson, Research Civil Engineer, Civil Engineering Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) and Philip Tilton, Structural Engineer, Metcalf & Eddy Inc./Engineers (M&E). The study was prepared for and funded by the DEW Systems Office of the U.S. Air Force, Aerospace Defense Command under MIPR CS 79-162.

Charles Korhonen of CRREL was Task Leader for the 1979 comprehensive DYE-2 performance survey. Herbert Ueda of CRREL was Task Leader for the 1979 sway bolt load measurement program. Mr. Ueda also led the effort to obtain and analyze core samples of the snow along the track of a sideways move. Barry Coutermarsh and Mark Goff of CRREL and Dr. Henning Agerskov and Karl Nielsen of the Structural Research Laboratory of the Technical University of Denmark also participated in the 1979 data collection program at DYE-2. Alan Greatorex of CRREL assisted in the assembly of equipment for that program.

We held several meetings at DYE-2 to develop the recommendations contained in this report. In addition to the authors, Mr. Korhonen, Mr. Ueda, and Dr. Agerskov participated. Their valuable comments and suggestions helped shape our recommendations.

John Rand of CRREL developed the water well feasibility study and cost estimate.

This report was technically reviewed by Mr. Korhonen, Mr. Rand, Mr. Ueda and Mr. Edward Lobacz of CRREL and Mr. J. Cassidy of M&E.

Prepublication copies of this report were submitted to the Air Force in December 1979.

CONTENTS Page

ILLUSTRATIONS

Figure

TABLES

EXTENDING THE USEFUL LIFE OF DYE-2 TO 1986

PART II: 1979 FINDINGS AND FINAL RECOMMENDATIONS

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INTRODUCTION

Part I of this report (Tobiasson et al. 1979) contains the following conclusions and recommendations:

1. A major construction effort is necesary within the next few years to extend the useful life of DYE-2 to 1986.

2. The structural steel frame is overstressed in a few areas but the increase in secondary stress with time appears to be slight. A comprehensive set of sway bolt load measurements is needed in 1979 to verify this trend. If secondary stresses are not accumulating rapidly, it may be possible to use the existing structural system to 1986.

3. The truss enclosure (see Fig. 1) is the structure's weak link. It is in bad condition below elevation 52.5* and will not last until 1986. A comprehensive inspection should be made in 1979 to verify this conclusion and to better establish the rate of deterioration.

4. It is probably not technically or economically feasible to extend the useful life of DYE-2 by completely rebuilding the truss enclosure.

5. It <u>does</u> appear technically and economically feasible to encapsulate the lower half of the truss enclosure (i.e. up to elevation 52.5) in ice. This would prevent further downward telescoping of the portion above elevation 52.5, which is in good condition.

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* These "elevations" are with reference to the bottom collar of the lower truss which had an assumed elevation of 0.0 in 1959. Because the truss enclosure is telescoping and differential movement has occurred between the trusses and the enclosure, these "elevations" no longer represent actual elevations. However, they are a valuable reference for locating items within the truss enclosure.

6. The ice backfill alternative was not selected for use at DYE-3 in 1977 because a new truss enclosure above elevation 52.5 would have been needed there and the level of secondary stress in the structural frame would have necessitated severing the columns at the top of the ice backfill and creating new supports there. At DYE-2 these added expenses can probably be avoided.

7. The DYE-2 building should be raised in 1981 or 1982. A lift of as little as 12 ft should suffice to extend its life to 1986.

8. A 210-ft sideways move of DYE-2, as was successfully accomplished at DYE-3 in 1977, is also technically feasible. Girder sections and other equipment returned to Sondrestrom AB after the DYE-3 move could be reused at DYE-2.

9. Additional core samples of the snow along the track of the proposed DYE-2 move should be obtained and tested for strength in 1979.

In accordance with recommendations for further study made in Part I of this report, the following programs were accomplished at DYE-2 during the summer of 1979:

1. Comprehensive performance survey.

2. Comprehensive set of sway bolt load measurements.

3. Strength analysis of snow along the track of the potential sideways move.

4. Joint CRREL-M&E on-site inspection and evaluation of life extension alternatives.

The details of these tasks are to be reported separately. The essence of each task is presented in this report; we will discuss the ice backfill and sideways move alternatives in light of the new information collected in 1979.

As the 1979 field program commenced, the Aerospace Defense Command (ADCOM) indicated that they may not need the DYE sites through 1986. At their request we investigated compromise methods of extending the useful life of DYE-2 for shorter periods and methods that defer capital investments. This report also contains that information.

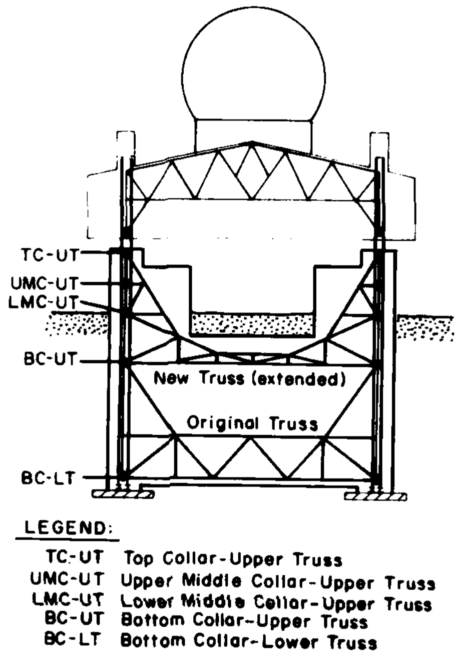

Figure 1. Elevation view of DYE-2.

1979 FINDINGS

Snow Accumulation

Between the summers of 1978 and 1979, 4.2 ft of new snow accumulated at DYE-2. This is a significant increase over the average accumulation of 2.6 ft/yr during the period 1959-1979.

The footings were 32 ft below the snow surface when DYE-2 was built in 1959. In 1979 they were about 102 ft below the snow surface in the immediate vicinity of the building, a change of 70 ft in 20 years or 3.5 ft/yr. Between 1973 and 1979 the footing depth increased from 78 ft to 102 ft, indicating an increase in the net build-up rate to 4 ft/yr. The reason for the increase to 4 ft/yr in recent years is that backfilling under the building has been progressing at a faster rate than the snow build-up in the vicinity. As a result, the building is located on a mound that is about 20 ft higher than the "natural" snow surface in the area (see Fig. 2).

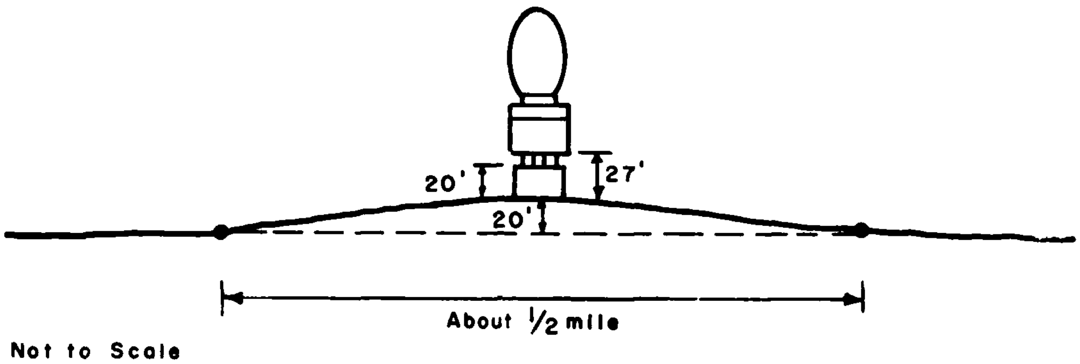

Figure 2. 1979 snow profile of mound at DYE-2.

This is a favorable position but there is no compelling need to increase the height of the mound each passing year relative to the "natural" snow surface. Consequently the DYE-2 life extension can be designed based on a 3-ft/yr build-up rate. At this rate the snow surface would be within 6 ft of the underside of the composite building in 1986 (see Fig. 3). To prevent excessive snow drifting around the facility the building should

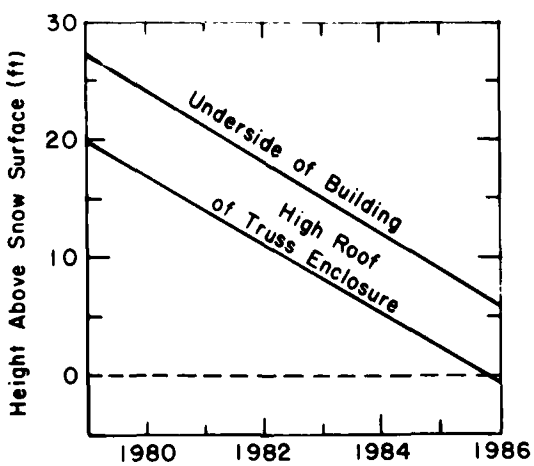

Figure 3. Building and truss enclosure clearances with time.

be maintained 15 ft or more above the snow surface. Using this criterion the building should be raised no later than 1983.

With the existing structural designs and systems it is most convenient to lift the building either 15 ft or 27 ft. If the building is lifted 15 ft in 1982 or 1983, the clearance in 1986 will be about 21 ft. Since this is adequate for snow control purposes, a 15-ft lift is all that will be needed to extend the useful life of DYE-2 to 1986.

As shown in Figure 2 the top of the truss enclosure will be slightly below the snow surface in 1986. Although this may create some minor problems, it is probably better than raising the roof of the truss enclosure 8 ft in conjunction with the life extension operation. If raised, the protruding portion of the truss enclosure will act as a snow fence and somewhat increase snow accumulation around the building.

A low truss enclosure roof creates a hazard since an operator may inadvertently drive a vehicle over the low roof if it is partially snow-covered. Even though portions of the truss enclosure currently protrude 20 ft above the snow surface, lower portions of the stepped lateral (A to N) enclosure roofs were at the snow level in 1979. Station personnel were warned about the hazard of "dropping a cat" down into the 100-ft-deep truss enclosure and a recommendation was made to the lead mechanic and station chief that bamboo poles and rope be used to cordon off the hazardous areas. This procedure, if implemented, would minimize current and future hazards associated with low truss enclosure roofs. Therefore, there is little need to raise the truss enclosure prior to 1986. Some periodic attention will be needed to seal out meltwater which drips into the truss enclosure roof from the roof of the composite building and to slope the surrounding snow away from the truss enclosure to prevent summer meltwater from entering the subsurface cavity.

The position of the snow surface is also an important consideration if the building is to be moved sideways in 1981 or 1982. Figure 4 shows snow surface elevations along the track of a sideways move, the estimated 1981 snow surface along the tracks, and the elevation of the column splice that corresponds to the splice separated for the DYE-3 move. If the snow surface permits, DYE-2 should be separated at this splice since the DYE-3 design could then be reused without much modification. Figure 4 also shows the elevation of the footings based on the footing-girder geometry used for the DYE-3 move. At this elevation the new footings would be at least 17 ft below the 1981 snow surface. Since a depth of at least 15 ft is desired for load bearing and thermal protection and a depth of less than 20 ft is desired to minimize costs, the DYE-3 sideways move geometry is appropriate to reuse at DYE-2. If the move is delayed until 1982, 3 to 3 1/2 ft of additional excavation will be necessary for the footings. This would be acceptable and would add little to the cost of the move.

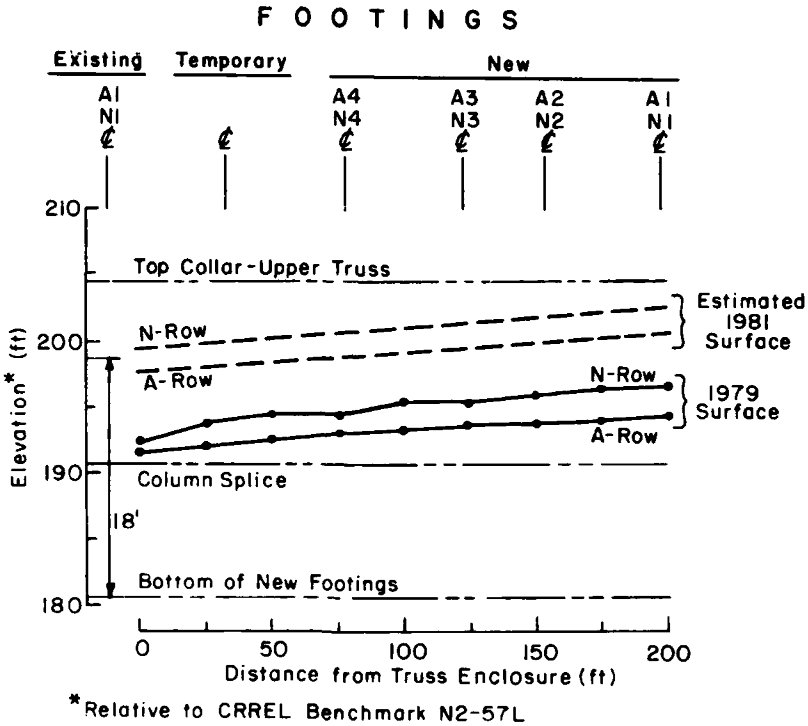

Figure 4. Elevations along the track of a sideways move.

Snow Strength

Snow studies conducted at DYE-3 prior to the sideways move are summarized by Tobiasson (1979). In 1979 a CRREL coring auger (Ueda et al. 1975) was used to obtain 3-in.-diameter cores of the snow to a depth of 50 ft at five positions along the track of a potential sideways move at DYE-2. Figure 5 indicates the locations of the five boreholes. Samples were stored at 15°F in the truss enclosure, then sized and tested at 20°F in unconfined compression at a cross-head speed of about 2 in./min. Visually, most of the samples resembled ice more than snow. A few relatively thin, weak granular layers were detected but most of the samples were very strong. Overall the snow that would support DYE-2 during a sideways move was significantly stronger than the snow that supported DYE-3 structure during the sideways move. Based on this information it is considered safe to support the DYE-2 structure on this snow during a sideways move.

Concern for inadvertent warming of the supporting snow during a sideways move was expressed in Part I of this report. It is considered important to create retaining walls and a white fabric cover over the new foundation as shown in Figure 4 of Part I.

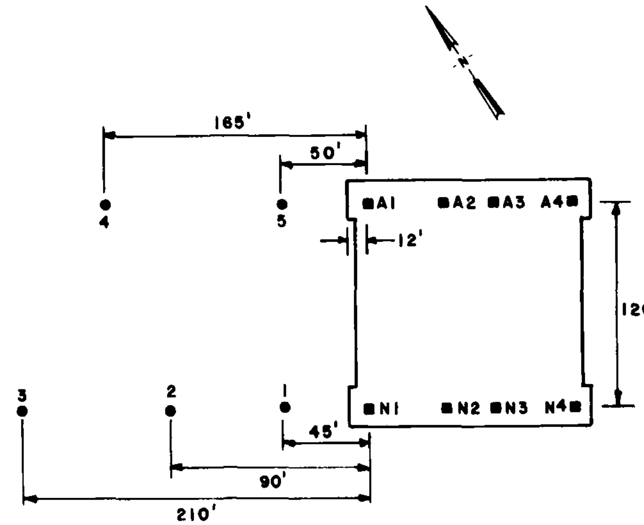

Figure 5. Location of five 1979 boreholes.

Settlement and Tilt of Existing Footings

Elevation surveys conducted in 1979 indicate that existing settlement and tilt trends are continuing. Footing A4 has settled less than all other footings. Table 1 presents each footing's settlement since construction relative to footing A4.

Table 1. 1978 and 1979 footing settlement (in.) relative to footing A4

Footing	Settlement, 1959-1978	Settlement, 1959-1979	Settlement, 1978-79
A1	21 1/2	23 3/4	2 1/4
A2	5 3/4	7 1/2	1 3/4
A3	1/2	1 1/2	1
A4	0	0	0
N1	32 1/4	35	2 3/4
N2	22 3/4	25	2 1/4
N3	22	24 1/4	2 1/4
N4	25	26	1

Almost 3 ft of differential settlement has occurred between footings A4 and N1. The amount of differential settlement is continuing to increase with time.

Early in the life of DYE-2 the subsurface trusses were periodically releveled to account for differential footing settlement. No truss releveling has been accomplished for several years because of the risk of buckling the extended columns. Collar A4 is the highest of the top collars of the upper truss. Other top collars are below it by the amounts shown in Table 2.

Table 2. Distance that each top collar of the upper truss is below the A4 collar.

Collar	Vertical distance (in.)
A1	11 1/4
A2	5 1/2
A3	2 1/2
A4	0
N1	17
N2	12
N3	11
N4	9 1/2

The differences in Table 2 account for a portion of the secondary stresses in the structural frame of DYE-2. Since the amount of differential settlement is continuing to increase (see Table 1), the magnitude of secondary stresses also can be expected to increase.

The composite building was last leveled in 1976 during the life extension operation. Differential settlements since that time have caused it to be out of level by the amount shown in Table 3.

Table 3. Distances that the first floor column rooms of DYE-2 are below the first floor in the A4 column room.

Column room	Vertical distance (in.)
A1	3 1/4
A2	5 3/4
A3	1 1/2
A4	0
N1	6
N2	4
N3	3
N4	2 1/2

The building can tolerate 10 in. of vertical displacement along its diagonals. However the difference of 4 1/4 in. between column rooms A2 and A3, which are only 30 ft apart, is of some concern. The building should be raised 2 or 3 in. at column A2 before any life extension work is accomplished.

All footings tilt away from the centerline of the building. Since the footings and columns are attached, the columns are forced to tilt at their bases. The base connections are not strong enough to resist the high stresses caused by footing tilt and in some areas have yielded. Gaps are now evident between columns and baseplates in several areas as shown in Figure 6. Because of the magnitude of footing tilt at column A1,

Figure 6. Gaps between columns and baseplates. The crack in the ice along the top of the baseplate is graphic evidence that a gap has developed there recently.

the base connection there was released during the 1976 life extension and diagonal braces were installed to transfer loads from the outer column half to the inner column half. A large gap currently exists between a portion of the A1 column and its baseplate (Fig. 7). The columns do not bear uniformly on their base plates.

Sway Bolt Measurements

A comprehensive sway bolt measurement program was conducted at DYE-2 in 1979 in accordance with the procedure discussed by Tobiasson et al. (1974). The total load measured at all sway bolts is an indication of

Figure 7. Large gap at base of column A1.

the level of secondary stress in the structural frame. That load, normalized by dividing it by the load measured at all sway bolts in 1972, is presented as a load factor in Figure 8. Since all sway bolts were loosened and the trusses were leveled during the 1970 life-extension operation, it has been assumed that the sway bolts were free of load at that time. The variation in load factor for the three checked collars monitored on more frequent occasions over the past eight years is also presented in Figure 8. It is evident that the level of secondary stress in the structural frame has decreased slightly since 1977. This is fortunate.

Lateral sway bolt loads induce bending stresses in the columns as

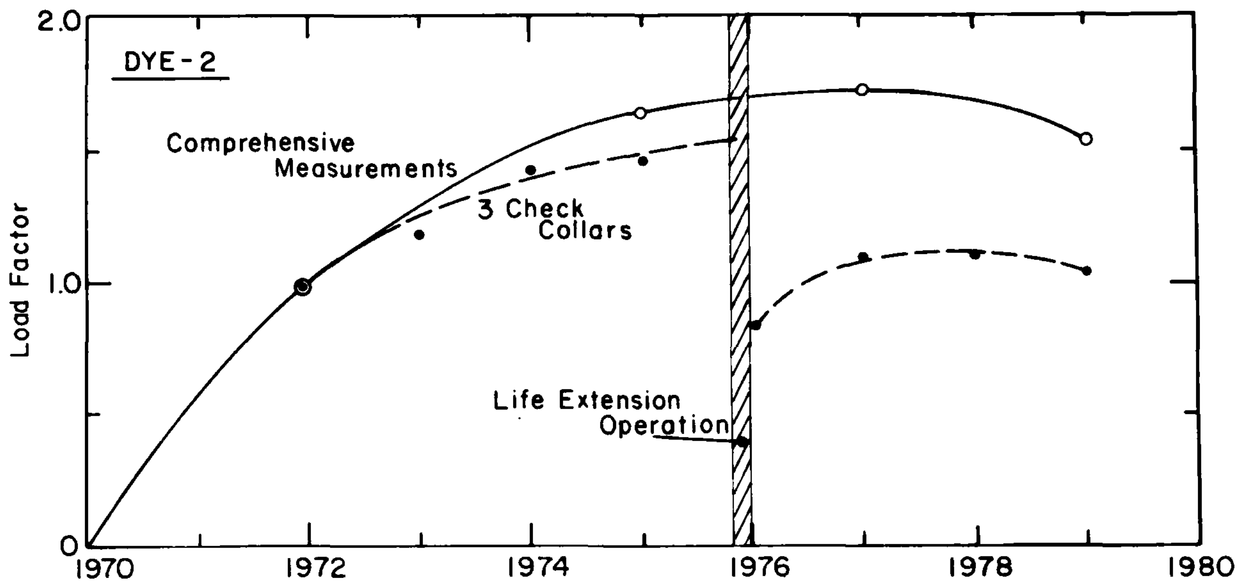

Figure 8. Load factor vs time.

the weight of the suspended building induces axial loads in them. Part I of this report describes the design equation given in the AISC Manual of Steel Construction for design of compression members subjected to combined axial and bending loads. Maximum allowable loads are reached when the "combined load factor" equals 1.0. When the "combined load factor" exceeds 1.0 the member is overstressed. If the factor equals 2.0 the combined load is twice the allowable. Combined load factors generated from the 1975, 1977, and 1979 comprehensive sway bolt measurement programs are presented in Table 4 for the bottom collar of the lower truss and the bottom collar of the upper truss (see Fig. 1).

Table 4. Combined load factors, DYE-2

	Bottom collar - lower truss*			Bottom collar - upper truss**		
Column	1975	1977	1979	1975	1977	1979
A1	2.36	1.47	1.16	0.94	0.74	0.69
A2	0.98	1.18	1.57	0.91	0.58	0.30
A3	0.78	1.44	1.31	0.69	0.43	0.38
A4	0.66	1.09	2.07	0.31	0.59	0.98
N1	1.12	0.83	0.39	0.49	0.30	0.20
N2	0.92	2.28	0.68	0.38	1.12	0.55
N3	1.29	1.28	1.39	0.49	0.51	0.93
N4	0.91	0.88	1.18	0.49	0.41	0.54

* near the column base
** about 50 ft above the column base

Table 4 is based on measurements that were made during essentially calm conditions. Tobiasson et al. (1974) indicate that design winds would only slightly increase the combined load factors presented in Table 4.

Six of the eight columns are stressed above the allowable value at the bottom collar of the lower truss. The combined load factor there averages 1.26. The amount of overstress at A1 is not great (the combined load factor equals 1.16), but at column A4 a significant overstress is present (combined load factor 2.07). The degree of overstress at the bottom collar of the lower truss severely limits the useful life of the existing structural system.

None of the columns are overstressed at the bottom collar of the upper truss. The combined load factor there averages only 0.57. However at columns A4 and N3 it is close to 1.0.

Unfortunately no clear trend is evident in the combined load factors presented in Table 4. Since 1975 some increase and some decrease, and at N2 they go up dramatically, then go down. Load adjustments conducted by CRREL personnel in August of 1977, some time after the 1977 readings in Table 4 were obtained, probably explain most of this confusing behavior. Those adjustments were made to reduce the combined load factors of column N2. It is apparent that the desired reduction was accomplished and the effect persists since the N2 load factors are low in 1979. The August 1977 load adjustments that relieved stresses in column N2 are believed responsible for the significant increase in load factors for column A4 from 1977 to 1979.

Sway bolt adjustments can move secondary loads about within the structural frame but not necessarily remove them. Based on the significant changes achieved by the 1977 load adjustment program it is felt that the high combined load factors at the bottom collar of the upper truss (0.98 at A4 and 0.93 at N3) should be reduced to less than 0.75 at the expense of slight increases in the low combined load factors of the other six columns at this level.

The expected benefits of a sway bolt adjustment program prior to an ice backfill operation and the slight decrease in the total sway bolt loads from 1977 to 1979 (see Fig. 8) indicate that there should be no need to sever the DYE-2 columns just above an ice backfill to relieve secondary stresses as would have been necessary at DYE-3. This will greatly simplify the ice backfill alternative for DYE-2.

Truss Enclosure Inspection

We spent several days crawling around the truss enclosure, determining its current condition which we compared to the findings of prior inspections. The lateral strengthening added in prior life extensions has essentially eliminated failure mechanisms related to lateral pressure. However the entire outer wall of the truss enclosure is incapable of resisting the persistent vertical draw-down forces generated by the adjacent densifying snow. Horizontal plates in that wall at several elevations below elevation 52.5 have failed (Fig. 9). Without their support the wall simply moves downward along with the adjacent densifying snow. The new portion of the truss enclosure in the N4 corner, built in 1976, is supported on a new plate at elevation 17.0. That plate has now failed.

Figure 9. Failed plates in wall of truss enclosure.

Enough downward movement has occurred in several areas to cause struts to interfere with the trusses. Interferences in the A4 - N4 lateral enclosure are shown in Figure 10. Enclosure/truss interferences induce large secondary stress in the structural frame and should be eliminated. A modest annual program to eliminate interferences should commence in 1980.

Areas that deserve immediate attention include:

Elev. 6.5

Walkway between A4 and N4 near N4
Walkway between A3 and N3 (two places)
Walkway between A1 and N1

Elev. 17.0

Walkway between A1 and N1 near N1

Elev. 22.3

Strut between A4 and N4 near A4
Walkway between A2 and N2 near A2 (two places)
Walkway between A1 and N1 near A1

Elev. 29.5

N1 steel waler

Elev. 32.5

Walkway between A1 and N1 near N1

Elev. 42.5

Roof at all columns except N4
Strut between A4 and N4 near A4

Elev. 48.5

Roof at several columns (minor)

Elev. 52.5

Walkway between A1 and N1 near A1 and near N1

Elev. 59.0

Two struts half way between A4 and N4
Two struts half way between A1 and N1

Elev. 62.8

Walkway on inner wall between A1 and A2 (two places)
Walkway on inner wall between A3 and A4 (one place)
Walkway on inner wall between N1 and N2 (several places)
Walkway between A1 and N1 near N1
Walkway between A2 and N2 near N2

Elev. 68.8

Several struts along the A-row
Several struts along the N-row

Figure 10. Enclosure/truss interferences in the A4-M4 lateral enclosure.

Elev. 83.8

Ladder between A1 and A2
Walkway between A1 and N1 near A1
Walkway between N1 and N2

To minimize the build-up of secondary stress in the substructure we consider it prudent to eliminate interferences on an annual basis from this time until the bottom half of the truss enclosure has been backfilled with ice or the building has been moved sideways onto a new foundation.

As part of the 1979 truss enclosure inspection, seven dial extensometers were installed between the columns and the truss enclosure to measure the rate of downward movement of the truss enclosure. Figure 11 shows the location of each extensometer; Figure 12 shows a typical installation. A set of readings we took in late July and another set taken by station personnel on 1 September were used to establish the rates of downward movement presented in Table 5.

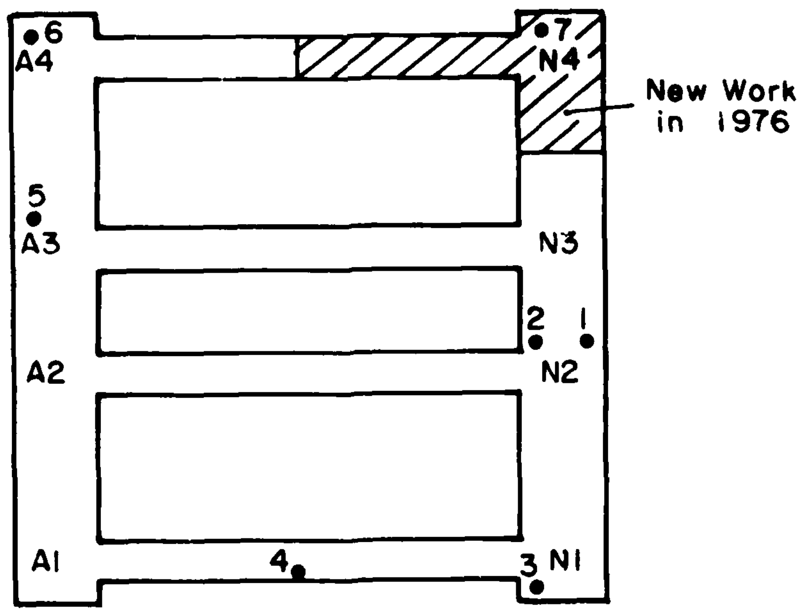

Figure 11. Location of dial extensometers.

Table 5. Rates of downward movement of the DYE-2 truss enclosure.

Dial extensometer no.	Rate (in./yr)
1	3 1/2
2	2 1/2
3	4
4	2 1/2
5	3 1/2
6	6
7	1 1/4

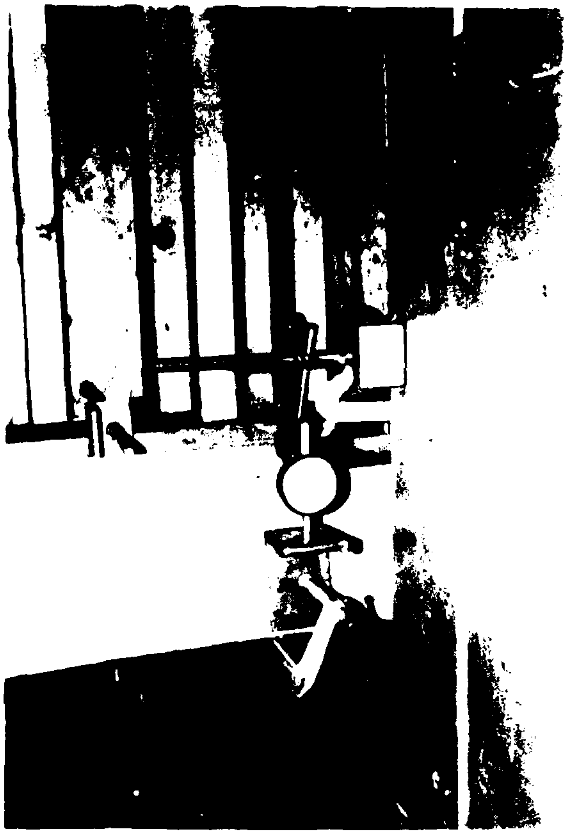

Figure 12. Typical dial extensometer installation.

At the above rates of movement, numerous interferences and other displacement-related problems will occur during the next few years. The draw-down forces appear to be too great for there to be an economical method of strengthening the truss enclosure to sustain them.

About the only way to stop the destructive telescoping action of the truss enclosure would be to backfill the lower half of the truss enclosure with ice. If the ice backfill extended up to within a few feet of the bottom collar of the upper truss, it would encapsulate all the failed plates and thereby stabilize the portion of the truss enclosure above. The upper portion of the truss enclosure is distorted and out of plumb. However it is structurally sound and should be capable of functioning as intended to 1986 if supported by an ice backfill instead of by the telescoping lower enclosure.

Since each passing day brings new interference problems, the ice backfill alternative, if selected, should be initiated as soon as possible. The winter of 1980-81 is probably the earliest such as operation could commence; that is none too soon.

Fuel Storage System

The existing fuel storage system needs some attention. The main access shaft into the buried fuel tunnel and the emergency exit at the other end of the tunnel are choked with snow. There are large piles of snow in the pump houses. The only way into the pump houses is by way of a vertical shaft above one pump house. All shafts and vent pipes terminate at or below the snow surface. Action was being taken by station personnel during our visit to find and extend the shafts. The fuel supply lines to the day tank in the building are out of sight in the snow-filled entrance shaft. They pass through the wall of that shaft below the snow surface and consequently are buried in snow for several feet before they rise up in the air toward the elevated composite building. Out of sight, they are also out of mind. During our comprehensive inspection of the truss enclosure, diesel fuel was noted on the outer wall of the A4-N4 lateral enclosure. Although fuel has been detected there before, dripping fuel and puddles of fuel on the ice at the bottom of that enclosure were noted this year for the first time. Station personnel located and repaired one leaking fuel line connection during our visit.

In addition to the snow removal requirements mentioned above, the rigid pipes in the lateral tunnels should be replaced by flexible hoses. These pipes are bowed and are twisting the fuel lines in the main tunnel.

Station records of the depth of fuel in each tank have been examined for several years. When fuel is not being added to a tank or removed for use by the station, the depth has remained essentially constant.

Since this applies to all four tanks at DYE-2 it provides evidence that the tanks are structurally sound and are not leaking.

In 1970 the DYE-2 buried fuel storage tanks were strengthened to sustain lateral and vertical loads associated with an 86-ft-deep snow cover over the top of each tank. Coincidentally, in 1979 the tanks were covered by 86 ft of snow. In 1986 about 110 ft of snow will cover the tanks. The extra 24 ft of snow will increase the direct overburden load on the roof of the buried tanks by about 35%. Perhaps this amount of overstress is acceptable.

The pumps should be able to deliver fuel at an acceptable rate working under the extra head associated with a 15-ft lift of the building prior to 1986. They should also be capable of functioning as required if the building is moved sideways 210 ft.

Since a replacement fuel storage system will cost over one million dollars there is considerable incentive to continue with the existing fuel storage system to 1986. The architectural-engineering firm chosen to do the life extension work should review all tank structural calculations and as-built drawings, then examine the tanks and recommend a course of action. There is a good chance that such a study will indicate that the existing system can be used without much modification until 1986.

It is suggested that fuel depth readings be taken every two weeks rather than every month beginning as soon as possible and that station and headquarters personnel examine them on a regular basis for leakage.

If the USAF does not wish to continue with the existing system, a replacement system similar to the new system of bladders in vaults built at DYE-3 in 1977 could be built. The system at DYE-3 can be improved by:

1. Constructing two long arched vaults to house the bladders rather than four short ones.

2. Providing two aircraft off-load pump/meter/filter systems and two, rather than eight, systems to deliver fuel to the day tank.

3. Reducing the size of the pumps which supply the day tank.

4. Providing more flexibility in the plumbing within the fuel tunnel.

5. Providing a more flexible bladder venting system.

6. Providing more space between the arched vaults.

Assembling the metal-arch vaults at DYE-3 was difficult and time-consuming. Although it would probably require more steel, a rectangular bladder storage facility similar to that shown in Figure 13 may be more economical since it would be far simpler to build.

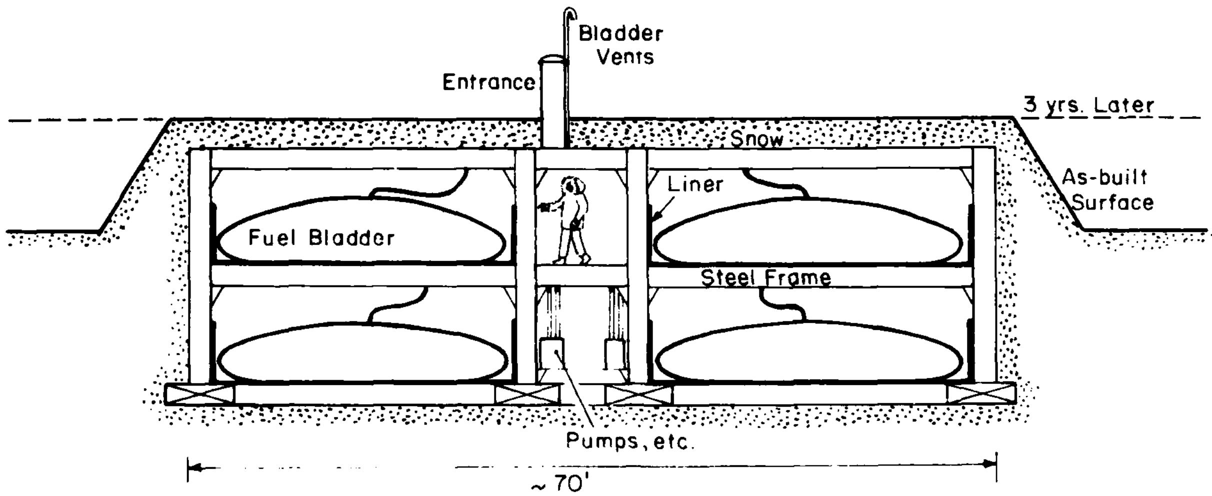

Figure 13. Concept for a rectangular bladder storage system.

Wastewater Disposal System

Because large discontinuous ice lenses and layers of very permeable granular depth hoar occur naturally in the snow at DYE-2, the DYE-2 wastewater disposal sumps behave more irregularly than do those at DYE-3. The wastewater disposal sump in use during our site visit had been used since August 1978. In May 1979 the liquid had risen until only 12 ft of freeboard existed below the sewer tunnel floor. In the past when such a limited amount of freeboard existed, wastewater was diverted to another disposal point. However, measurements taken in July and August 1979 indicated that the water level in the sump had dropped significantly. In August, 39 ft of freeboard was present. Since August, the water level has risen rapidly; in October, only 15 ft of freeboard was present. Figure 14 shows the irregular growth of this sump.

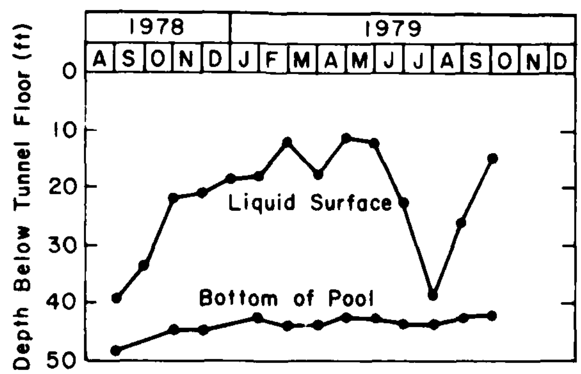

Figure 14. Growth of wastewater disposal sump B-2.

Station personnel were advised that a new wastewater disposal point should be readied at the junction of the main and branch tunnels but sewage should be discharged at the existing sump until the freeboard decreases to 10 ft.

Temperature sensors installed several years ago in the snow at various depths below the main and branch sewer tunnels indicate that the sewage that has "escaped" from the existing sump has probably flowed along a high permeability granular layer toward the branch tunnel but not toward the composite building where it could adversely warm the supporting snow.

Once in use, the new wastewater disposal point should serve station needs for about two years. Therefore, a new wastewater disposal system should be installed in conjunction with other work planned for DYE-2 in 1981 or 1982.

In addition to the new ideas used for the DYE-3 wastewater disposal system built in 1977, the following additional improvements should be incorporated:

1. Omnidirectional snow-free vent covers should be installed on all vents (see Figs. 41 and 42 of Tobiasson et al. 1975).

2. The entrance shaft should not be directly under the wall of the composite building but moved further away so a 5-ft horizontal offset exists. This will reduce the amount of meltwater that runs into the tunnel from the building.

3. The hatch and ladder of the entrance shaft should be reconfigured so personnel are not required to crawl around the wastewater disposal hose when entering or exiting the tunnel.

4. Enough extension pieces for the extrance shaft and the vent to last for the full projected life should be provided and warehoused on site as part of the life-extension contract.

An electrical hot point should be designed and built to make pilot holes for wastewater disposal sumps. A 3-in.-diameter hot point equipped with a 1- to 2-kilowatt heating element and 150 ft of electrical cable is suggested. It will greatly simplify the sump initiation operation which now requires the use of a steam generator which must be brought to DYE-2 or DYE-3 for each occasion.

Instead of the tunnels that have been used successfully at DYE-2 and DYE-3 for many years, an elevated insulated pipeline equipped with electrical heating elements (see Fig. 15) should be considered. This alternative would be cheaper than a system of tunnels.

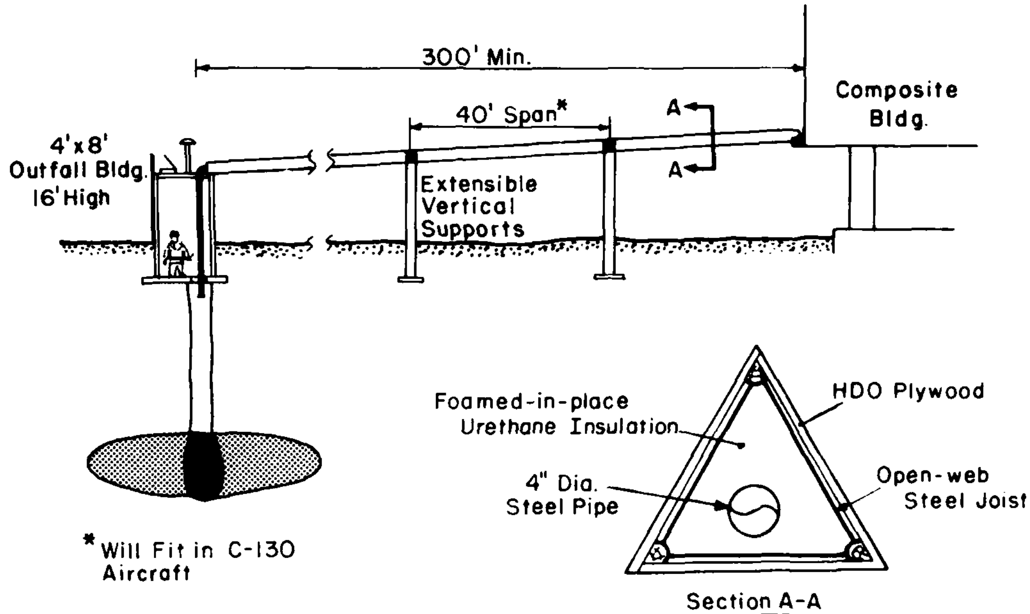

Figure 15. Concept for an elevated wastewater disposal system.

LIFE-EXTENSION ALTERNATIVES

Conventional Lift

DYE-3 was moved sideways rather than lifted at this point in its life. Consequently, DYE-3 cannot provide prior experience for this step at DYE-2 as it has for prior DYE-2 life extensions. A comprehensive structural analysis will be required to determine the implications of lifting DYE-2. As stated previously, a lift of as little as 15 ft will extend the useful life of DYE-2 to 1986.

If DYE-2 is lifted and a complete truss enclosure is retained (i.e. the lower portion is not backfilled with ice) it will be necessary to replace the lower 50 ft of the truss enclosure. If this must be done we expect that it would be easier, less expensive, and safer to replace the entire truss enclosure rather than just the lower 50 ft.

While examining the existing truss enclosure we discussed the alternative of replacing it with an entirely new truss enclosure of a different design to avoid the problems that have plagued the existing enclosure. We are not sure how to design such a structure, given the loads and differential footing settlements that must be accommodated. In addition to the technical unknowns associated with this alternative, it seems certain that removing the existing truss enclosure and constructing a new stronger truss enclosure would be extremely expensive. In our judgment, technical uncertainties and excessive costs combine to eliminate this approach from further consideration.

Sideways Move

A 210-ft sideways move of DYE-2 as was accomplished at DYE-3 in 1977 is probably the most reliable alternative available, considering the success of the DYE-3 move and the results of snow studies conducted at DYE-2 in 1979. Tobiasson (1979) briefly describes the DYE-3 move. The elevation of the DYE-2 snow surface in 1981 will be such that the same column splice can be used for the DYE-2 move as was used at DYE-3. Therefore, the design of the DYE-3 sideways move and much of the equipment used there can be reused at DYE-2 with little, if any, modification.

Prior to moving DYE-3 the snow was excavated from above the roof of the A1-N1 lateral truss enclosure and that area was rebuilt. This should not be necessary at DYE-2. However, as previously stated in this report, enclosure/truss interferences in the DYE-2 enclosure should be eliminated on an annual basis from this time until life extension plans are implemented.

The snow at DYE-2 that will be excavated to make space for new footings and for the sideways-move girders will be more difficult to handle than the snow removed at DYE-3. At DYE-2 some of that material, particularly that near the existing structure, is more like ice than snow.

One precaution will be needed at DYE-2 that was not used at DYE-3. This involves construction of retaining walls alongside the girders, shading the footing with a white fabric cover (see Fig. 4 of Part I) and grading the surface away from this area to minimize warming of the supporting snow by sunlight and meltwater infiltration.

It seems appropriate to move the DYE-2 building one summer season, then raise it the following year as was done at DYE-3. A 15-ft lift will suffice to extend the useful life of DYE-2 to 1986.

Each passing day brings additional interference problems in the truss enclosure. Because of this it seems best to move DYE-2 sideways as soon as possible. Considering the time required to plan and mobilize for major life-extension work at the DYE sites, the earliest this could be accomplished is 1981.

Since secondary stresses are not as great or increasing as rapidly in the DYE-2 structural frame as they were at DYE-3, it should be possible to delay the DYE-2 sideways move to 1982 and perhaps even to 1983 if an annual program of interference elimination is initiated in 1980. We do not recommend delaying until 1982 or 1983 but these options are open to the U.S. Air Force as methods of postponing major capital commitments. It must be realized that as time passes, the risk of structural problems increases. With the information we have at this time it seems unwise to delay until 1982 and technically wrong to delay beyond 1983. Unless there is a compelling reason to delay until 1982, the move should occur in 1981.

If a sideways move were the least expensive method of extending the useful life of DYE-2 to 1986 it should certainly be used. Cost comparisons presented in a subsequent section of this report will show that this is not the case.

Ice Backfill

The 1979 measurement program verified that the ice backfill alternative is more appealing at DYE-2 than it was at DYE-3 for two reasons:

1. Secondary stresses in the structural frame of DYE-2 are generally not excessive and are not increasing (Fig. 7). Therefore, there is no compelling need to sever the eight columns at the top of the ice backfill to relieve stresses in the structural frame.

2. If the ice backfill is accomplished soon, the truss enclosure above elevation 52.5 can be retained with little additional work.

We devoted considerable time and effort to the technical and economic questions associated with this alternative for DYE-2. Of the two ice backfill techniques presented by Hanamoto et al. (1976), we strongly favor the water spray method over the snow-water slurry method. We doubt that the slurry method is capable of creating the homogeneous solid-ice backfill needed to encapsulate the substructure of the facility.

Expeditious stabilization of the truss enclosure is warranted. If the ice backfill is chosen, a major effort should be made to accomplish it as soon as possible.

The backfill operation would proceed during the winter months when fans could be used to blow in cold surface air to freeze the water spray.

We investigated three methods of creating the water needed for the ice backfill:

1. Use of the snow melter that currently provides water for DYE-2.

2. Use of a new oil-fired snow melter on the surface and a front-end loader.

3. Creation of a subsurface water well.

The slack line excavator and snow melter at DYE-2 which provide water for station use are mechanically and thermally incapable of providing the estimated 20,000 gallons of water needed daily to completely backfill the truss enclosure to elevation 52.5 during one winter. It seems necessary to provide separate snow melting equipment for this operation.

Oil-fired snow melters are commercially available that could melt enough snow each day to create 20,000 gallons of water. One such snow melter and one front-end loader tending it around the clock could generate enough water in four months to complete the ice backfill. However, the winter months are horrible times for surface operations such as snow collection. Although this method of creating water is feasible it would be difficult and potentially dangerous.

The idea of creating a subsurface water supply by melting a cavity in the ice cap is quite appealing as it would eliminate the need for surface operations during the winter. Furthermore, less than half the fuel consumed by a snow melter should be needed to create the subsurface water supply (Mellor 1969). Such pools were used to supply water and dispose of waste heat for the nuclear power plant at Camp Century, Greenland (Mellor 1969, Schmitt and Rodriguez 1960). All well-head equipment could be housed in a temporary heated building within a few hundred feet of DYE-2. Difficulties associated with walking between the well-head building and DYE-2 would be minimal. Oil-fired boilers, water pumps, and other equipment of the capacity needed for this task are available commercially. The subsurface pool should be created during the fall.

The ice cap at DYE-2 is impermeable to water below a depth of about 130 ft so no lateral percolation of meltwater occurs. The 2.8 million gallons of water needed for the backfill could be stored in a paraboloidal cavity with a maximum diameter of about 125 ft and a depth of about 70 ft. The top of this cavity would be about 150 ft below the snow surface.

As the reservoir is used during the following winter, only a few kilowatts of electrical power would be necessary to warm the pool to keep ice from forming at its surface around electrical and water lines.

After the ice backfill is complete the empty cavity could serve a valuable purpose: wastewater from DYE-2 could be discharged into it. The cavity would have ample capacity to handle all of the station's liquid waste through 1986.

No matter what method is used to provide water, electrically-heated insulated water-supply lines will be needed to carry the liquid to hoses and spray nozzles within the truss enclosure. Large fans and large diameter piping would direct cold, dry winter air down into the area where the water is being sprayed to freeze the water spray in thin layers. If thick layers of water are allowed to form it will be very difficult and time consuming to freeze them. Therefore the cold air cooling system will have to be adaptable enough to allow direction of the cooling air at the water spray as it hits the ice.

The ice backfill task is, in principle, straightforward. However, it is difficult to predict how simple or complex it will be in practice. On one hand it can be argued that once the hardware is established, a couple of workers periodically redirecting the water spray and air hoses should be able be keep the operation going with little difficulty. On the other hand, considerable effort may be required to avoid freezing within the hoses and prevent deep water ponds which would be difficult to freeze.

The ice backfill must be an "engineered product." It will be necessary to monitor the temperatures near the base of the backfill as it is formed to avoid excess warming of the snow under the footings. At the beginning of the ice backfill operation it will be important to prevent water from seeping into the supporting snow below the footings. Third party inspection will be required to assure that no voids are created in the backfill. It will be very important to fill all areas within the truss enclsoure with ice. This includes the difficult-to-reach confined areas below the base plate of each footing.

While it is considered technically reasonable to plan on a one-season ice backfill operation and it is advantageous to complete the backfill as quickly as possible, it must be acknowledged that the rate of production of this unique task has been estimated by extrapolating from a small-scale, short-duration field study at DYE-3. While it is desirable to create the entire backfill in one season, it may not be possible to accomplish it. The contract should acknowledge this and not penalize the contractor if the backfill can not be completed during the 1980-81 winter. However, there should be some incentive in the contract to complete it in one season.

We recommend against spreading the backfill operation out over several winters so the existing DYE-2 snow melter can be used through a small add-on contract to the existing service contract.

As stated previously the truss enclosure need not be raised to extend its useful life to 1986 but the building should be. If the ice backfill is completed during the winter of 1980-81, the building could be raised as early as the summer of 1981. However, it would be technically acceptable to delay the raise until 1982 or 1983.

We feel that an ice backfill is a viable approach for extending the useful life of DYE-2 to 1986 and perhaps beyond. However, it is difficult to speculate on the usefulness of the iced-in substructure beyond 1986. The most conservative attitude is to assume that if a life extension beyond 1986 is needed, a sideways move will be necessary at that time. There is a reasonable chance that in 1986 more of the truss enclosure could be backfilled with ice at less expense than a sideways move. Monitoring the performance of the ice backfill during the early 1980's will answer this question.

PRELIMINARY COST ESTIMATES

General

Cost estimates in this report are based on 1977 costs escalated by 18% to generate 1979 costs. To generate costs for operations to be accomplished in 1981, 1982, and 1983 the 1979 costs were multiplied by 1.18, 1.28, and 1.39 respectively. These costs include contractor overhead and profit but do not include design or inspection costs associated with the projects.

Detailed cost figures for all operations are presented in Appendix A. The costs of major items as a function of the several years in which they could be performed are summarized in Table 6.

Sideways Move

Those costs in Table 6 associated with a sideways move of DYE-2 are based on reuse of Air Force equipment made for the DYE-3 move and currently stockpiled at Sondrestrom Air Base.

Estimated costs associated with extending the useful life of DYE-2 by moving the building sideways in 1981 are itemized below:

Eliminate enclosure/truss interferences in 1980	$27,000
Eliminate enclosure/truss interferences in 1981	32,000
Level the building in 1981	40,000
Sway bolt load adjustments in 1981	35,000
Sideways move in 1981	4,055,000
Rehabilitate the existing fuel storage system in 1981	72,000
Extend the fuel storage system sideways 210 ft in 1981	165,000

Table 6. Costs associated with major components of DYE-2 life extension alternatives

Component	Cost in thousands of dollars 1979	1981	1982	1983
Eliminate enclosure/truss interferences	27	32	35	38
Level building	34	40	44	47
Sway bolt load adjustments	30	35	38	42
210 ft sideways move	3436	4055	4398	4776
Raise building 15 ft*	717	846	918	997
Ice backfill using water well	1014	1197	1298	1409
Ice backfill using snow melter	1281	1512	1640	1781
Raise building 15 ft**	1150	1357	1472	1600
Raise building an additional 12 ft	910	1047	1165	1265
Rehabilitate fuel storage facilities	61	72	78	85
Extend existing fuel lines 210 ft	140	165	179	195
New fuel storage facilities similar to those at DYE-3	1325	1564	1696	1842
New wastewater disposal system, similar to existing	160	189	205	222

* In conjunction with sideways move
** In conjunction with ice backfill

Construct a new wastewater disposal system in 1981	189,000
Raise building 15 ft in 1982	918,000
Total costs	$5,533,000

If the existing fuel storage system were abandoned and a new fuel storage system like the one constructed at DYE-3 in 1977 were built, the total cost would increase by about 1.33 million dollars to 6.9 million dollars.

Ice Backfill

Estimated costs of extending the life of DYE-2 to 1986 by backfilling the truss enclosure to elevation 52.5 during the 1980-81 winter, using a deep well for water and raising the building in 1981 are itemized below:

Eliminate enclosure/truss interferences in 1980	27,000
Level the building in 1980 (average of 1979 and 1981 costs in Table 6)	37,000
Sway bolt load adjustments in 1980	32,000
Ice backfill during the 1980-81 winter (average of 1979 and 1981 costs in Table 6)	1,106,000
Raise the building 15 ft in 1981	1,357,000
Rehabilitate the fuel storage system in 1981	72,000
Construct a new wastewater disposal system in 1981	189,000
Total costs	2,820,000

If a bucket loader and a surface snow melter were used rather than a deep well, the cost would be almost $300,000 more.

If the existing fuel storage system were abandoned and a new fuel storage system were built like the one built at DYE-3 in 1977, the total cost of either ice backfill alternative would increase by about $1.5 million.

Cost Comparisons

The above costs indicate that about $2.7 million could be saved if the useful life of DYE-2 is extended by backfilling the bottom half of the truss enclosure with ice rather than moving the building sideways 210 ft onto new foundations. At DYE-3 a sideways move was a less expensive alternative than an ice backfill. At DYE-2 this is not the case since costs associated with a new truss enclosure above elevation 52.5, with severing each column, and with providing a new load transfer system at elevation 52.5, are unnecessary. Furthermore, additional studies of the backfill incorporating a deep well water supply has decreased the cost estimate of that operation below the estimate given by Metcalf & Eddy Inc. for the DYE-3 ice backfill.

Other cost comparisons can be made for the delayed utilization of various life extension alternatives with the information in Table 1. For example, raising the building only 15 ft rather than 27 ft as has been done in the past will save over $1 million.

CONCLUSIONS AND RECOMMENDATIONS

The results of our 1979 on-site measurement program confirmed our preliminary findings that a major construction effort is needed at DYE-2 to extend its useful life to 1986. Because of the rapidly deteriorating condition of the truss enclosure, the life extension effort should commence as soon as possible. The truss enclosure does not need to be extended upward and the composite building needs to be lifted only 15 ft.

A 210-ft sideways move is technically feasible and relatively simple since the design and equipment used at DYE-3 in 1977 can be used with few changes at DYE-2. However, at DYE-2 a sideways move is expected to cost about $2.7 million more than the alternative of backfilling the truss enclosure with ice.

The ice backfill, while not as reliable a method as the once-proven sideways move, is considered technically feasible.

If there is a strong possibility that DYE-2 will not be needed beyond 1986 we recommend that the ice backfill alternative be adopted.

If there is a strong possiblity that DYE-2 will be needed for many years beyond 1986 it may be prudent to invest in that future now and pay the extra cost of a sideways move. This would facilitate future life extensions beyond 1986. Such life extensions should also be possible if the ice backfill method is used but it is possible that they would include a sideways move in 1986.

If the likelihood of needing DYE-2 beyond 1986 lies between the two extremes discussed above, we suggest that the ice backfill method be considered seriously since it would cost far less.

No matter which alternative is chosen, it is technically best to implement it as soon as possible. However, a sideways move or an ice backfill could be delayed for a year or two (i.e. the ice backfill could be formed during the winter of 1981-82 or 1982-83 or the building moved sideways in 1982 or 1983). If such delays occur, enclosure/truss interference problems must be eliminated annually.

A new wastewater disposal system will be needed at DYE-2 in 1981 or 1982. An elevated pipeline should be considered in lieu of the expensive subsurface tunnel used in the past.

If the ice backfill alternative is used at DYE-2 and a water well is used to supply the water, the empty cavity should be used as a wastewater sump.

The existing fuel storage system needs some attention. Although it is at the end of its calculated design life, it will probably perform satisfactorily for several more years. Because a replacement system will cost over a million dollars, there is considerable incentive to use the existing system as long as possible.

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APPENDIX A: ITEMIZED COST ESTIMATES

Itemized cost estimates for:

1. Preliminaries
2. Sideways move
3. Ice backfill using front-end loader and snow melter
4. Ice backfill using water well
5. 15-ft lift in conjunction with sideways move
6. 15-ft lift in conjunction with ice backfill
7. Additional 12-ft lift with either a move or a backfill
8. Rehabilitation of existing fuel storage system
9. 210-ft sideways extension of existing fuel storage system
10. Construction of a new fuel storage system (bladders in vaults as at DYE-3)
11. New wastewater disposal system (pipe in tunnel)

PRELIMINARIES

Line	Item	Unit	Quan.	Material Unit	Material Total	Labor Costs Man Days	Labor Costs Rate	Labor Costs Total	Other Direct	Total (based on 1977 costs)
1	Eliminate enclosure/ truss inter- ferences	L.S.*								
	1979 Total									27,000
2	Level build- ing	L.S.				110	161.85	17,800	4000	22,000
	OH&P at 32%									7,000
	Total									29,000
	1979 Total									34,000

*L.S. = lump sum

15-FT LIFT IN CONJUNCTION WITH SIDEWAYS MOVE

Line	Item	Unit	Quan.	Material Costs Unit	Material Costs Total	Labor Costs Man days	Labor Costs Rate	Labor Costs Total	Other Direct Costs	Total 1977 Prices
1	Erect. Col. Ext.	Ton	103	770	79310	454	161	73,090	32,800	185,200
2	Raise Bldg.	--	--	--	--	764	161	123,000	55,000	178,000
3	Raise Trusses	--	--	--	--	275	163	44,830	20,100	65,000
4	Mob. & Demob.	L.S.								32,000
	Subtotal									$460,000
	OH&P at 32%									147,300
	Total									$607,300
	1979 Total 607,300 x 1.18 =									$717,000

15-FT LIFT IN CONJUNCTION WITH ICE BACKFILL

Subtotal as above	460,000
New Trusses - See Item 5d of Sideways move	278,400
Subtotal	738,400
OH&P at 32%	236,300
Total	$974,700
1979 Total 974,700 x 1.18 =	$1,150,000

SIDEWAYS MOVE

Line	Item		Unit	Quan.	Material Costs: Unit	Material Costs: Total	Labor Costs: Man days	Labor Costs: Rate	Labor Costs: Total	Other Direct Costs	1977 Costs
1	Mobilization		L.S.	--	--	140,900	252	161.90	40,800	18,300	200,000
2	Site Work		L.S.	--	--	--	63	142.00	8,950	32,300	41,300
3	Demolition		L.S.	--	--	--	210	162.00	34,020	15,000	49,000
4	Extend Util.		L.S.	--	--	2,200	51	162.85	8,300	1,500	12,000
5	Struct. Steel										
5a	Girders	New Salv.	Ton Ton	139 268	770 --	17,030 --	1,408	161.00	226,690	83,000	416,700
5b	Footings	New Salv.	Ton Ton	250 63	770 --	192,500 --	1,720	161.00	276,900	102,000	517,400
5c	Col. Load Trans.		Ton	100	--	--	440	161.00	70,840	26,200	97,000
5d	New Trusses		Ton	160	770	123,200	703	161	113,200	42,000	278,400
6	Footing Lumber		MBFM	45	701	31,545	267	162.85	43,480	19,650	94,700
7	Install Move Equip.		L.S.	--	--	123,600	174	162.85	28,340	3,152	155,100
8	Move Bldg.		L.S.	--	--	--	231	161.00	37,191	--	37,200
9	Connect to Footings		L.S.	--	--	--	84	207.00	17,390	2,010	19,400
10	Footing & Col. Encl.										
10a	Lumber		MBFM	40	700	28,000	240	161.00	38,640	17,360	84,000
10b	Struct. Steel		Ton	64	770	49,280	268	161.00	43,150	19,300	111,730
11	Salvage		--	--	--	--	70	161.00	11,270	5,000	16,270
12	Final Site Work		--	--	--	--	32	142.00	4,544	17,000	21,600
Subtotal											$2,205,800
OH&P at 32%											705,856
Total											2,911,656
1979 Total = $2,911,656 x 1.18 =											$3,436,000

ICE BACKFILL USING FRONT-END LOADER AND SNOW MELTER

Line	Item	Unit	Quan.	Material Costs: Unit	Material Costs: Total	Labor Costs: Man days	Labor Costs: Rate	Labor Costs: Total	Other Direct Costs	1977 Costs
1	Snow Melter				25,000				2,500	27,500
2	Air Moving Equip.				30,000				3,000	33,000
3	Piping				5,000				500	5,500
4	Front-end loader				100,000				10,000	110,000
5	Fuel	Gal.	134,000	$2.00	268,000				26,800	294,800
6	Foreman					150	171	25,650	5,130	30,800
7	Install Equip.					180	162	29,160	5,830	35,000
8	Install Backfill					1,400	160	224,000	44,800	268,800
9	Mob. & Demob.					62	162	10,000	2,000	17,000
	Subtotal							172,000	76,350	822,400
	OH&P at 32%									263,200
	Total									1,085,600
	1979 Total = $1,085,600 x 1.18 =									$1,281,000

ICE BACKFILL USING WATER WELL

Line	Item	Material Total	Labor Total	Other Direct Costs	1977 Costs
1	Subtotal as above				822,400
2	Less snow melter and front-end loader	-125,000		-12,500	-137,500
3	Less fuel needed because of efficiency of well (needs 64,000 gallons)	-140,000		-14,000	-154,000
3	Add boiler, pumps, hoses, cables, etc.	85,000		10,000	95,000
4	Extra labor associated with well (beyond that saved by eliminating melter and front-end loader)		20,000	5,000	25,000
	Subtotal				650,900
	OH&P at 32%				208,300
	Total				859,200
	1979 Total = $859,200 x 1.18 =				$1,014,000

ADDITIONAL 12-FT LIFT WITH EITHER A MOVE OR A BACKFILL

Line	Item	Unit	Quan.	Material Costs Unit	Material Costs Total	Labor Costs Man days	Labor Costs Rate	Labor Costs Total	Other Direct Costs	Total 1977 Prices
1	Erect Col. Ext.	Ton	83	770	63,910	364	161	58,604	16,000	138,500
2	New Trusses	Ton	118	770	98,600	520	161	83,720	30,830	213,200
3	Raise Bldg.	L.S	--	--	--	610	161	98,210	50,000	148,200
4	Raise Trusses	L.S	--	--	--	221	163	36,000	16,300	52,300
5	Mob. & Demob.	L.S								32,000
	Subtotal									$584,200
	OH&P at 32%									186,900
	Total									771,100
	1979 Total 771,100 x 1.18 =									$910,000

REHABILITATION OF EXISTING FUEL STORAGE SYSTEM

Line	Item	Unit	Quan.	Material Costs Unit	Material Costs Total	Labor Costs Man days	Labor Costs Rate	Labor Costs Total	Other Direct Costs	Total 1977 Prices
1	Extend shafts	L.F.	150	125	18,750	24	163	3,912	1,760	24,422
2	Repair & replace pipe	L.S.								9,000
3	Electrical	L.S.								3,000
4	Clean-up	L.S.				12	162	1,824	820	2,644
	Subtotal									39,070
	OH&P at 32%									12,500
	Total									52,000
	1979 Total 52,000 x 1.18 =									$61,000

210-FT SIDEWAYS EXTENSION OF EXISTING FUEL STORAGE SYSTEM

Line	Item	Unit	Quan.	Material Costs Unit	Material Costs Total	Labor Costs Man days	Labor Costs Rate	Labor Costs Total	Other Direct Costs	Total 1977 Prices
1	Tunnels	L.F.	210	118	24,780	60	163	9,780	4,400	38,960
2	Shafts	L.F.	150	125	18,750	24	163	3,912	1,760	24,420
3	Extend Piping	L.S.	--	--	8,000	45	170	7,650	3,400	19,050
4	Electrical	L.S.	--	--	--	--	--	--	--	5,000
5	Repair & Replace Piping	L.S.	--	--	--	--	--	--	--	9,000
6	Clean-up	L.S.	--	--	--	--	--	--	--	2,500
	Subtotal									89,930
	OH&P at 32%									28,770
	Total									118,700
	1979 Total 118,700 x 1.18 =									$140,000

CONSTRUCTION OF A NEW FUEL STORAGE SYSTEM (BLADDERS IN VAULTS AS AT DYE-3)

Line	Item	Unit	Quan.	Material Costs Unit	Material Costs Total	Labor Costs Man days	Labor Costs Rate	Labor Costs Total	Other Direct Costs	Total 1977 Prices
1	Tank shelters	L.S.								392,660
2	Endwalls	L.S.								73,689
3	Tunnels	L.S.								112,811
4	Pumps, pipes, etc.	L.S.								127,140
5	Bladders	L.S.								144,630
	Subtotal									850,930
	OH&P at 32%									272,300
	Total									$1,123,230
	1979 Total = $1,123,230 x 1.18 =									$1,325,000

NEW WASTEWATER DISPOSAL SYSTEM (PIPE IN TUNNEL)

Line	Item	Unit	Quan.	Material Costs Unit	Material Costs Total	Labor Costs Man days	Labor Costs Rate	Labor Costs Total	Other Direct Costs	Total 1977 Prices
1	Tunnel	L.F.	450	127	57,150	125	163	20,400	8,500	86,050
2	Piping	L.F.	450	25	11,250	28	163	4,600	1,020	16,870
	Subtotal									102,920
	OH&P at 32%									32,934
	Total									135,850
	1979 Total 135,850 x 1.18									$160,000