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Memorandum

To: Truman Seamons, National Regulatory Commission, Washington, D.C.

From: Clarence O. Babcock, Supervisory Mining Engineer, Mine Design Division, Denver Research Center

Subject: Trip Report for May 17-19, 1982 Visit to NTS and Discussions with DOE

Many of the following comments were a part of the joint trip report prepared with Dr. Lawrence Chase, NRC, shortly after the completion of the subject meeting. Additional comments and emphasis in this report are mine.

First, and most important from my standpoint as a professional mining engineer, the problems associated with mining under conditions encountered nowhere else in the world at the present time are largely ignored. Such mining is not within the present state of the art. By far, the largest number of participants at the meeting were either geologists or hydrologists, and any consensus opinion would have a strong bias in favor of geology or water. I realize that the SCR will have a strong geology basis, but mining must be considered somewhere along the line. When? If a given mining method must be used, this could dictate the selection of the repository host rock.

Since mining in a rock mass with a temperature perhaps 200°C has not been done and the problems, including pressure buildup, cannot be ignored, I see little value in making heater tests as Sandia is doing with temperatures of 90°C. A graph of pressure versus temperature for water-steam is attached.

The NRC agreed with DOE that the concept of a controlled zone is necessary. This zone is to be negotiated with NRC on a site specific basis. The question was asked, "What body of information would provide the required statistical confidence?" The focus now is on the SCR. A thick detailed SCR is to be avoided. The BWIP SCR will be shared with DOE. The unit selection issues are: 1) Geology, 2) Hydrology, 3) Geotechnical, 4) Geochemical, 5) Mineralogy, and 6) (last) engineering (mining).

The ranking criteria will include: The isolation time which is most important of all, the gross thermal loading, and the economics. If all else is equal, the least costly method will be selected. The SCR is to be a progress report or snapshot of what is known.



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Memorandum to Mr. Seamons, NRC, Washington, D.C.

The contents of the SCR should include the natural seismicity of the NTS area. A maximum acceleration of 0.7 g is expected in a 15,000-year period. Yucca Mountain is seismically inactive. The 1700 KT nuclear expolosion at Buckboard Mesa was the largest shock with a frequency of 2 to 5 Hertz for the body wave.

At constant water content, the temperature has negligible effect on the rock strength. The welded tuff behavior is a linear function of temperature while the unwelded zeolitic tuffs have a complex behavior.

The drill holes used were not very straight at the NTS, some being 25 or 30 degrees off the vertical collar direction. The suitability of the rock as a mine structural material was barely touched and was discussed only briefly.

The in situ stress state in the "G" tunnel was determined by an overcoring method used by Sandia to be 8 mpa vertically and less than 1 and 5 mpa in the horizontal plane in orthogonal directions. The large room under 1300-1500 feet of cover stood well when bolted with 8' and 16' grouted bolts on 4-ft centers. A water return for the drill of 90 percent indicates that the rock is relatively tight. The vertical stress was in reasonable agreement with the overburden weight of about 10 mpa.

The area for waste storage is only marginally large enough for the intended purpose.

There are in excess of 3,000 drill holes in the NTS area, but data is missing for many of these. The flow direction for water around the NTS area is predominantly to the south and west. The water levels in wells cited were about 2,395 feet in 8 of 9 holes. This implies that the water table does not reflect the structure in the rock and is hydrologically connected from one area to the next.

The most permeability was in the topaz and bullfrog members. Below the bullfrog the permeability was very low. We do not have recognizable hydrological units. The data base we have to work with is minimal in nature.

Hydrofracturing was used to define something of the state of stress in the area. The greatest compressive stress was N15° E which is in agreement with normal faults in the area. The approach used was interesting but not very specific.

The most useful part of the meeting relative to the mining aspects was the presentation of Mr. Leo Scully, Sandia National Laboratory, who presented his conception for a mine layout in very broad and general terms in figure 1. He thought the shafts should be to the east of the repository zone. However, a shaft location on the west side was also considered. The access to the shafts should be by railroad probably from the north but perhaps from the south. An exploration shaft of 10 ft diameter would be sunk through the center of the repository horizon and ring drilling with 2,000 ft holes would be used to sample the rock mass over as large an area as possible. The men and materials and waste shaft would be of 22 ft diameter. He considered one scenario where the canisters would be placed vertically as in figure 2. They would produce an expected 2 Kw of heat per canister at a temperature of less than 400°C in the center of the waste and of 250°C in the rock mass. The wall temperature of the entry for placing canisters would reach 105°C in 35 years. The heat load would be 50-75 Kw/acre. Air conditioning with 24°C air at a flow rate of 1 meter/sec would reduce the temperature from 105°C to 40°C within 4 months when necessary for the operation of the repository. Another scenerio shown in figure 3 which he preferred was as follows. Two parallel drifts driven 600 feet apart on the same elevation would be connected by parallel drill holes normal to the drift directions. These holes would be filled with canisters for the center part of the holes but would be left empty for a selected distance from each end of the hole. The heat buildup around the canisters would be isolated from the drifts by this unloaded zone. The isotherms would radiate out from the waste with time allowing perhaps 50 years during which the drift or entry temperature would be low enough for mining operations, waste emplacement, etc. The holes would not be backfilled so that the rate of temperature buildup would be decreased. A retrieval would be easier, if necessary.

Another exploration scenario proposed (figure 4) was to sink a shaft of 10 ft diameter for the first phase, drive drifts 200 feet away from the shaft and then ring drill to define rock properties, extent, structural features, etc. Next, a second shaft of 16 ft diameter would be sunk 1,500 to 2,000 feet deep and connected to the first shaft. One item of interest was the use of natural ventilation to help cool the repository by using two shafts with collar elevations as different as possible, say 700 to 800 feet. Natural ventilation is as old as mining itself but is seldom counted on for ventilation in modern mines.

For physical property tests on tuff Sandia reported that there was no decrease in strength at confining pressures used in tests. Water was the most important variable weakening the rock mass as a result of pore pressures produced. Water greatly sensitized the material to time temperature effects. The strength decreased with strain rate as shown in figure 5. The creep behavior for the bullfrog tuff was rate dependent for saturated zones but was not rate dependent for dry tuff. The model shown in figure 6 was devised by Re/Spec. The behavior of the welded tuff is a linear function of the temperature. The unwelded tuff with zeolites have a complex behavior.

In a visit to the G-tunnel underground test facility operated by Sandia the following were observed: The drift stands open well with wire mesh and bolting support even for large room size in unwelded tuff. Bolts of resin anchor and expansion anchor type both seemed to work well in lengths of 8 and 16 feet spaced on 4 ft centers. In a stress relief test made under about 1,400 feet of overburden the stresses were found to be less than one megapascal in one horizontal direction, 5 megapascals in the other orthogonal direction in the horizontal plane, and 8 megapascals in the vertical direction. The weight of the overburden and the measured stress are in reasonable agreement.

Evaluation

The progress made by Sandia National Labs has been adequate in most but not all of the areas of their testing. In particular, the use of 90°C maximum heater temperature experiments are of a simplistic nature that avoid the effects of pressures created by water heated to steam when confined. In addition, the behavior of the salt with thermal stress is not defined. A very large part of the discussion centered on geology, hydrology and other rock-water relationships. This is in keeping with the present trend in rock mechanics that is currently in vogue that strongly emphasizes these aspects under the leadership of the University of California and others who largely ignore 23 years of reported rock mechanics related to mining that emphasizes structure and physical behavior of materials.

The testing of rock mechanics behavior in the laboratory largely for input to computer modeling alone is not an adequate end product as evidenced by the widely diverse results obtained by Sandia in their benchmark testing of 9 computer codes. The actual design of the mine structure itself should receive at least as much attention. This should include the behavior of rock as structural materials under elevated temperatures and under increased pressures. At the same time the strength of the rock is decreased by increased temperature, the pressures are increased. A structure designed for ambient temperatures and in situ stresses which is the present state-of-the-art for mining could be very different from one of best design for the repository conditions.

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Clarence O. Babcock

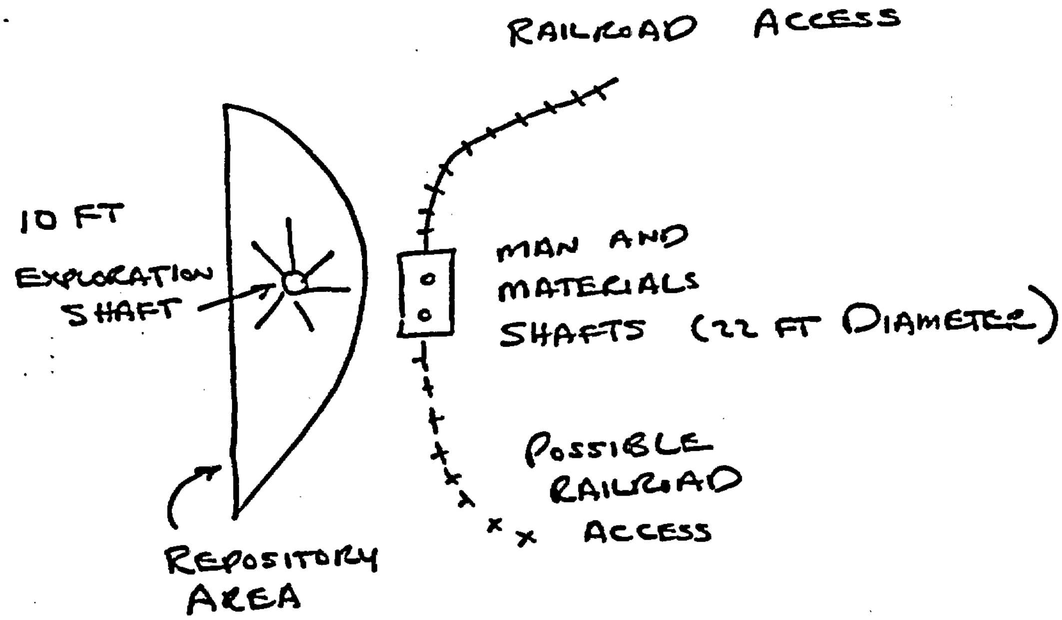
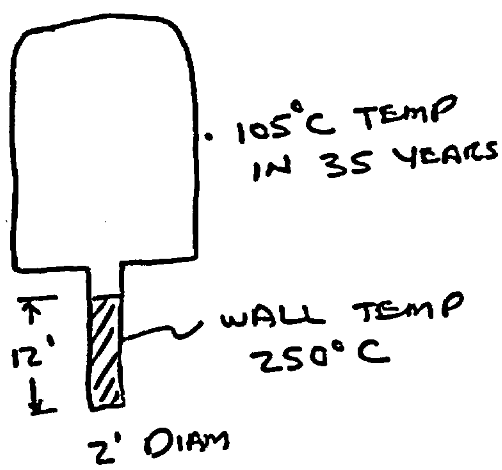



FIGURE 1.- SITE LAYOUT




- 50-75 KW/ACRE
- 2KW / CANISTER
- 24°C AIR FLOW OF 1 METER/SEC WILL COOL 105°C TEMP TO 40°C IN 4 MONTHS WHEN NECESSARY

FIGURE 2.- VERTICAL CANISTER EMPLACEMENT

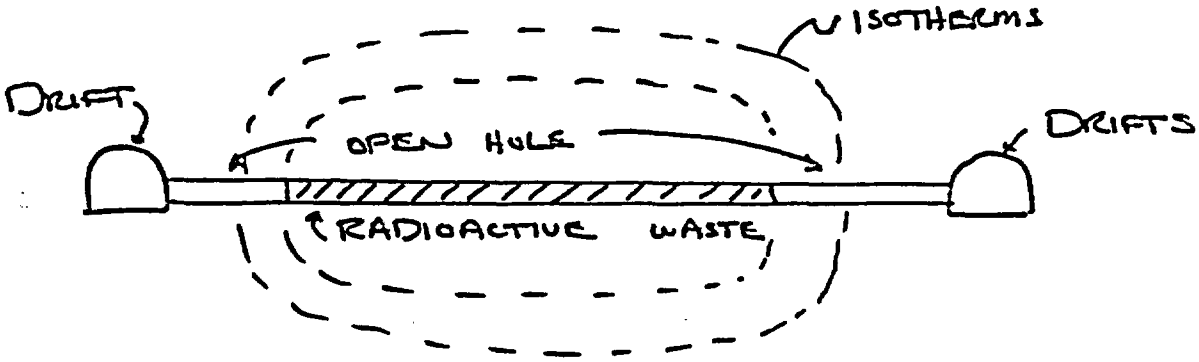
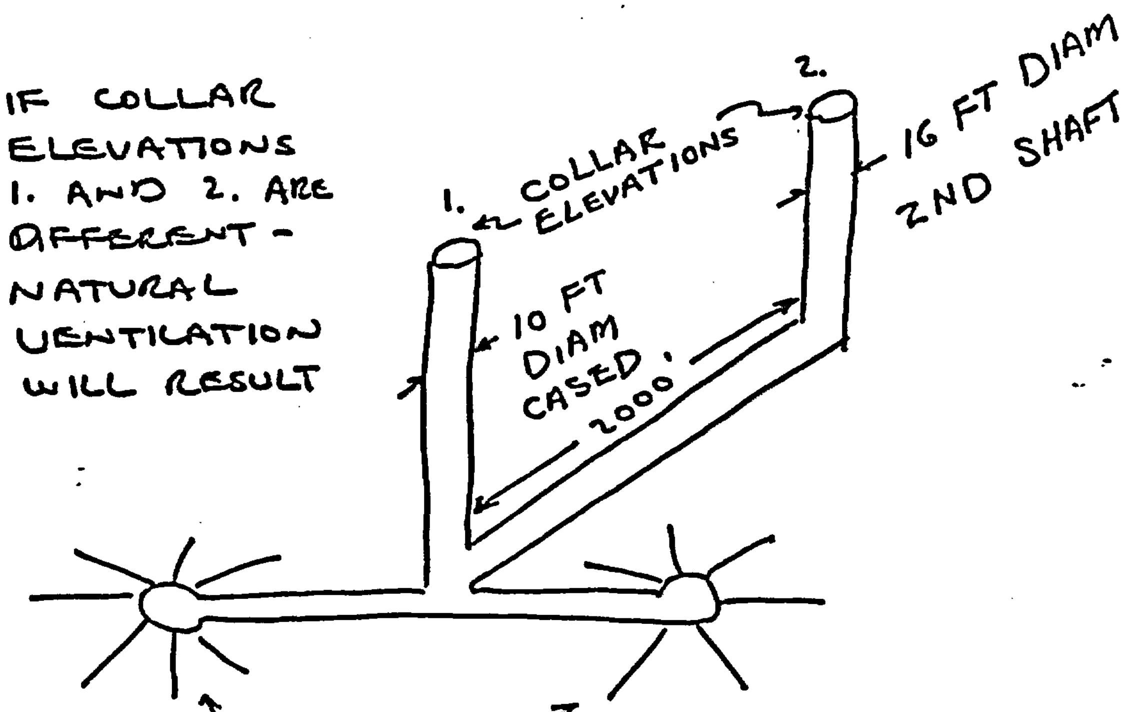



FIGURE 3. WASTE STORED IN CENTER OF LONG HOLES WILL NOT STRONGLY HEAT ENTRY DRIFTS




RING DRILLING FOR EXPLORATION AND PHYSICAL PROPERTY TESTING.

FIGURE 4.- SECOND EXPLORATION SCENARIO

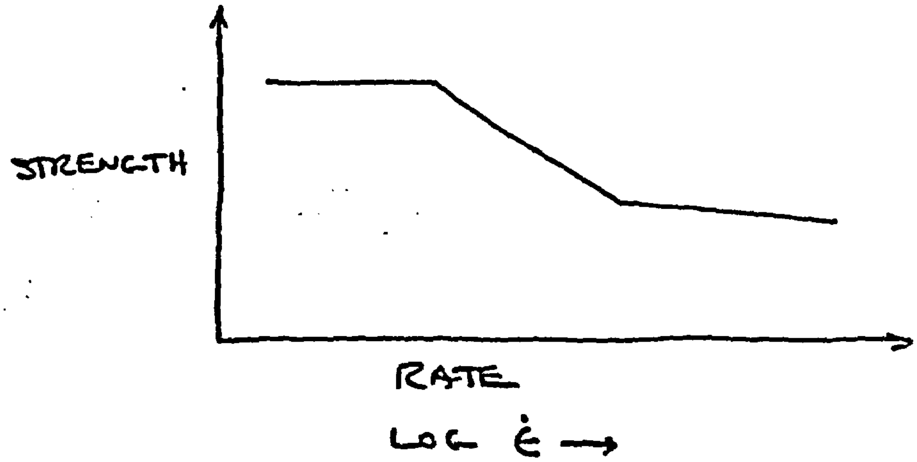



FIGURE 5.- DECREASE IN STRENGTH OF TUFF WITH STRAIN RATE

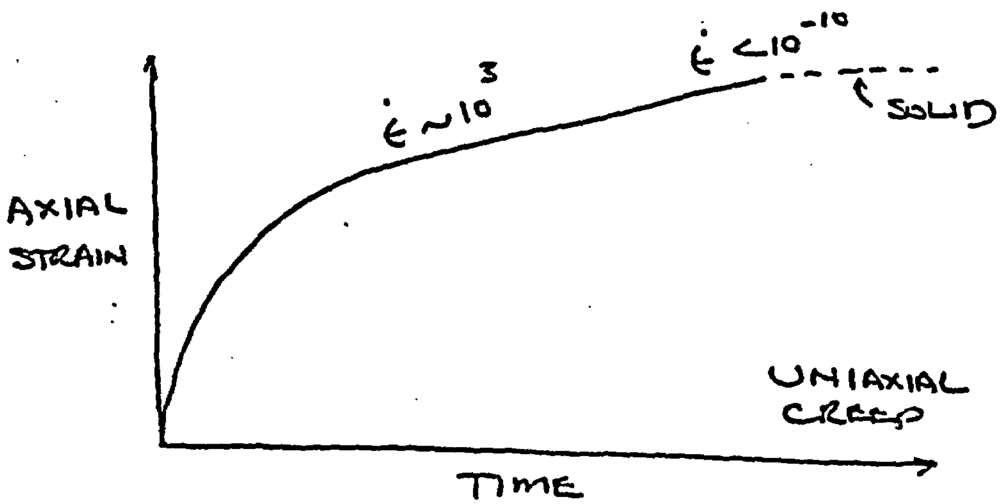
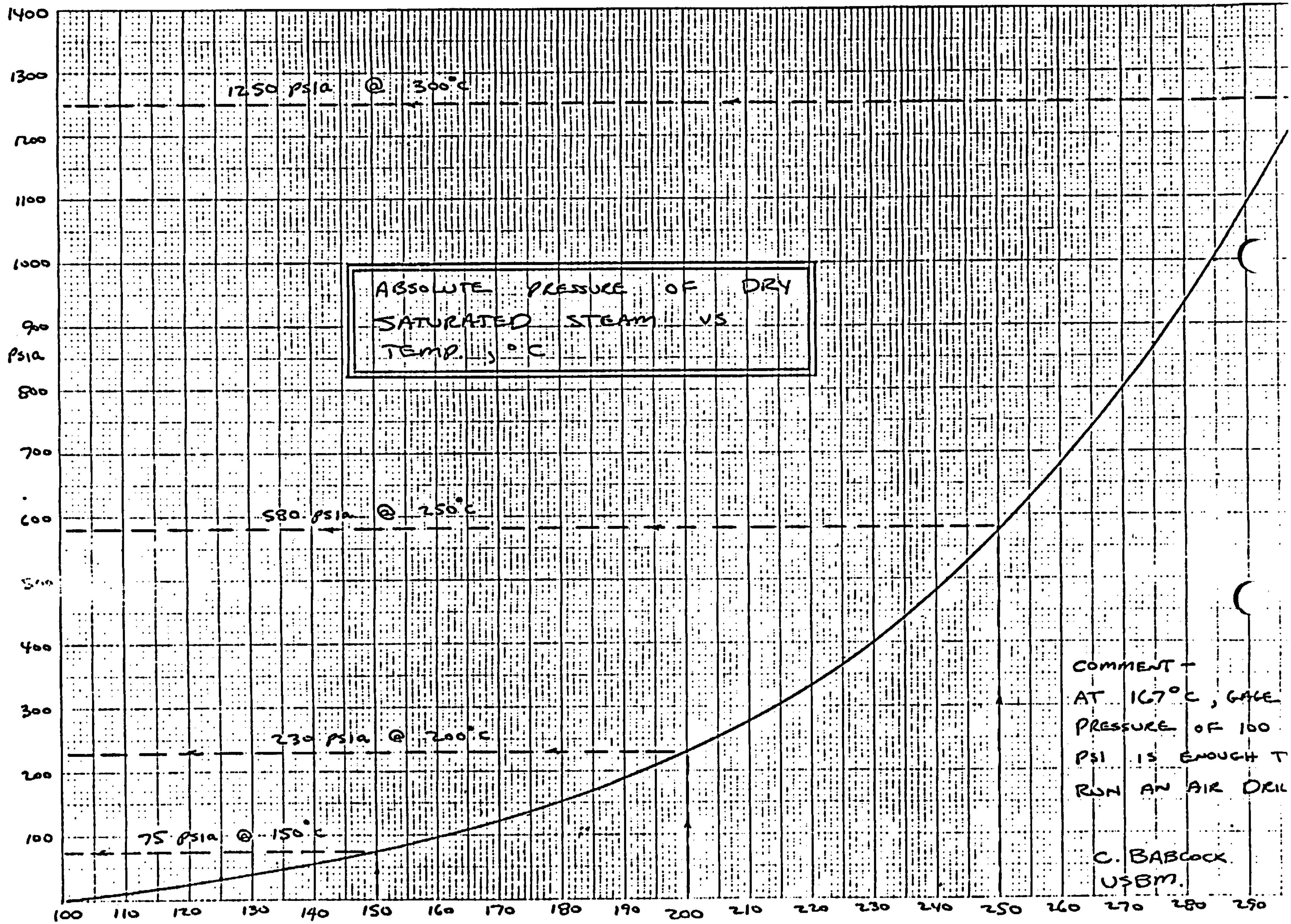



FIGURE 6. STRAIN IS BOUNDED FOR TUFF WHICH THEREFORE ACTS AS A SOLID AS $t \rightarrow \infty$ (RE/SPEC MODEL)


ABSOLUTE PRESSURE OF DRY SATURATED STEAM VS TEMP, °C
1250 psia @ 300°C
580 psia @ 250°C
230 psia @ 200°C
75 psia @ 150°C
psia
1400
1300
1200
1100
1000
900
800
700
600
400
300
200
100
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
COMMENT –
AT 167°C, GAGE PRESSURE OF 100 PSI IS ENOUGH T
RUN AN AIR DRIL
C. BABCOCK
USBM.