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ANNEXE I

Brevet

TILLIE A REMPLACE LES EXPRESSIONS DE LA DESCRIPTION DU DOCUMENT PCT **FR92 00323** REPORTEES SOUS (A), AVEC LES EXPRESSIONS REPORTEES SOUS (B)

EXTRAITS DU RAPPORT DIT DE LARRY FLAK (B)	EXTRAITS DE MES DESCRIPTIONS (A)
I ELEMENT SENSIBLE	PANTOGRAPHE
II POUVANT SE MOUVOIR DANS SIX DIRECTIONS	CENTRAGE
III PARTIE FRONTALE	DISPOSITIF D'OPPOSITION A LA PRESSION
IV SCELLAGE	BLOCAGE, PLOMBAGE
V GEOMETRIQUE	CONIQUE
VI SANS AUCUNE FUITES	PLOMBAGE
VII CONTROLANT L'ASSEMBLAGE DU STINGING	PERMETTANT LA PENETRATION DU SYSTEME
VIII L'ORIENTATION DE LA TRAJECTOIRE	LE CENTRAGE
IX UN SCELLEMENT ENTRE UN KILL SPOOL ET LE RESTE DE LA TETE DU PUITS	COMPORTANT UN SYSTEME D'OPPOSITION A LA PRESSION ET DE BLOCAGE PRINCIPAL AGISSANT SIMULTANEMENT SUR LA PARTIE LATERALE INTERIEURE DU PUITS PAR EXTENSION
X JOINT EN PLOMB	CYLINDRE EN PLOMB
XI RAINURE CIRCULAIRE	ENTOURANT L'AXE CENTRAL
XII ALESAGE INTERIEUR DU TUYAU	LA PARTIE LATERALE INTERIEURE DU PUITS
XIII LA RAINURE CIRCULAIRE	ENTRE LE REBORD (3) ET LE REBORD INFERIEUR DU CYLINDRE DU BLOCAGE PRINCIPAL (17)
XIV ETC	

EXTRAITS DES INVENTIONS CONCERNEES ET LA TRADUCTION LITTERALE DES PARAGRAPHES **NEW KILL SPOOL, STINGERS** ET LE PARAGRAPHE 2 DE **FIRE EXTINGUISHING METHOD**: PAGE 72 DE **WORLD OIL SPECIAL REPORT** DE MAI 1992, RAPPORT DE **LARRY FLA**

INVENTIONS CONCERNEES

I. LE KILL SPOOL EST L'INVENTION **PCT FR 92 00323** COMPORTANT LES PARTIES SUIVANTES :

i. LE SYSTEME D'OPPOSITION A LA PRESSION ET DE PLOMBAGE EN PLOMB, AGISSANT PAR EXTENSION A L'INTERIEUR DU PUITS PLOMBANT AUSSI LES USURES.

ii. LE SYSTEME DE BLOCAGE PRINCIPAL COMPORTANT UN AXE CENTRAL CONIQUE SUR CETTE PARTIE ET UN CYLINDRE COMPORTANT A L'INTERIEUR UN FRAISAGE CONIQUE ET UNE FENTE LONGITUDINALE, AGISSANT PAR EXTENSION SIMULTANEMENT AVEC LE SYSTEME D'OPPOSITION A LA PRESSION SUR LA PAROI INTERIEURE DU PUITS, L'AXE CENTRAL CONIQUE AYANT, EXEMPLE 50 % DE PLUS DE DIAMETRE DE LA DIFFERENCE DES DIAMETRES INTERIEURS CONIQUES DES DEUX EXTREMITES DU CYLINDRE.

iii. LE SYSTEME DE CENTRAGE PAR LE PRINCIPE DU PANTOGRAPHE.

II. LE STINGER A ETE MODIFIE AVEC LES SYSTEMES SUIVANTS DE L'INVENTION **PCT FR 92 00323**:

i. LE SYSTEME D'PPOSITION A LA PRESSION ET DE PLOMBAGE EN PLOMB, AGISSANT PAR EXTENSION A L'INTERIEUR DU PUITS PLOMBANT AUSSI LES USURES.

ii. LE SYSTEME DE BLOCAGE PRINCIPAL COMPORTANT UN AXE CENTRAL CONIQUE SUR CETTE PARTIE ET UN CYLINDRE COMPORTANT A L'INTERIEUR UN FRAISAGE CONIQUE ET UNE FENTE LONGITUDINALE, AGISSANT PAR EXTENSION SIMULTANEMENT AVEC LE SYSTEME D'OPPOSITION A LA PRESSION SUR LA PAROI INTERIEURE DU PUITS, L'AXE CENTRAL CONIQUE AYANT, EXEMPLE 50 % DE PLUS DE DIAMETRE DE LA DIFFERENCE DES DIAMETRES INTERIEURS CONIQUES DES DEUX EXTREMITES DU CYLINDRE.

iii. LE SYSTEME DE CENTRAGE PAR LE PRINCIPE DU PANTOGRAPHE.

III. LE SYSTEME D'EXTINCTION **PCT FR 92 00405** A ETE DECLARE LE MEILLEUR ET PREMIERE MONDIALE.

NEW KILL SPOOLS — NOUVEAU TUEUR DE FLUX

Des nouveaux KILL SPOOLS ont été développés comportant des scellement en plomb déformable.

STINGERS — SYSTEME DE BLOCAGE DE 1931

Des STINGERS comportant des géométries nouvelles ont été développés au KOWAIT.

FIRE EXTINGUISHING METHODS — PROCEDES D'EXTINCTION

Tout ces développements ont fait partie du cours normal du raffinement et l'innovation attendus de l'extraordinaire groupe des experts des champs pétroliers qui étaient rassemblés au KOWAIT. Des milliers de propositions ont été présentées pour contrôler l'extinction, mais aucune n'a eu aucun nouveau mérite. A la fin les clés du succès ont été des personnes qui ont l'expérience des champs pétroliers et qui ont tous ensemble débattu les problêmes et auxquels il avait été donné carte blanche pour les résoudre.

EXTRAITS DES INVENTIONS CONCERNEES ET LA TRADUCTION LITTERALE DU PARAGRAPHE **KILL SPOOLS AND STINGERS**, PAGE 75 DE **WORLD OIL SPECIAL REPORT** DE MAI 1992 RAPPORT DE **LARRY FLAK.**

INVENTIONS CONCERNEES

I. LE KILL SPOOL EST LE SYSTEME DE BLOCAGE **PCT FR 92 00323** COMPORTANT LES PARTIES SUIVANTES :

i. LE SYSTEME D'OPPOSITION A LA PRESSION ET DE PLOMBAGE EN PLOMB, AGISSANT PAR EXTENSION A L'INTERIEUR DU PUITS PLOMBANT AUSSI LES IMPERFECTIONS.

ii. LE SYSTEME DE BLOCAGE PRINCIPAL COMPORTANT UN AXE CENTRAL CONIQUE SUR CETTE PARTIE ET UN CYLINDRE COMPORTANT A L'INTERIEUR UN FRAISAGE CONIQUE ET UNE FENTE LONGITUDINALE, AGISSANT PAR EXTENSION SIMULTANEMENT AVEC LE SYSTEME D'OPPOSITION A LA PRESSION SUR LA PAROI INTERIEURE DU PUITS, L'AXE CENTRAL CONIQUE AYANT, EXEMPLE 50 % DE PLUS DE DIAMETRE DE LA DIFFERENCE DES DIAMETRES INTERIEURS CONIQUES DES DEUX EXTREMITES DU CYLINDRE.

iii. LE SYSTEME DE CENTRAGE PAR LE PRINCIPE DU PANTOGRAPHE.

II. LE STINGER A ETE MODIFIE AVEC LES MEMES SYSTEMES

i. LE SYSTEME D'OPPOSITION A LA PRESSION ET DE PLOMBAGE EN PLOMB, AGISSANT PAR EXTENSION A L'INTERIEUR DU PUITS PLOMBANT AUSSI LES USURES.

ii. LE SYSTEME DE BLOCAGE PRINCIPAL COMPORTANT UN AXE CENTRAL CONIQUE SUR CETTE PARTIE ET UN CYLINDRE COMPORTANT A L'INTERIEUR UN FRAISAGE CONIQUE ET UNE FENTE LONGITUDINALE, AGISSANT PAR EXTENSION SIMULTANEMENT AVEC LE SYSTEME D'OPPOSITION A LA PRESSION SUR LA PAROI INTERIEURE DU PUITS, L'AXE CENTRAL CONIQUE AYANT, EXEMPLE 50 % DE PLUS DE DIAMETRE DE LA DIFFERENCE DES DIAMETRES INTERIEURS CONIQUES DES DEUX EXTREMITES DU CYLINDRE.

iii. LE SYSTEME DE CENTRAGE PAR LE PRINCIPE DU PANTOGRAPHE

KILLS SPOOLS AND STINGERS — KILL SPOOLS ET STINGERS

ABB VETCO GRAY a dirigé l'atelier mécanique de la KOWAIT OIL COMPANY à AHMADI, et a été capable de développer des bouchons de tête pratiques et des STINGERS géométriques pour des applications spécifiques, généralement durant la nuit avec "l'impossible" en quelques jours, de nouveaux développements ont été fabriqués avec du plomb déformable de scellement KILL SPOOLS. Le plus significatif de ceux-ci a comporté du plomb déformable de scellement disposé de façon à faire un scellement entre un KILL SPOOL et le reste de la tête du puits (FIG. 7). Ceux-ci ont consisté en un joint en plomb monté dans une rainure circulaire réalisée dans la partie frontale (d'opposition à la pression) du KILL SPOOL qui devra faire le scellement frontal (d'opposition à la pression) entre l'alésage intérieur du tuyau et la rainure circulaire, ou alternativement dans la rainure circulaire. Dans beaucoup de cas, la déformation et/ou le craquelage se prolongeaient à travers la rainure circulaire de la tête de puits, nécessitant un scellement en dehors de l'alésage de la tête de puits mais à l'intérieur de la rainure circulaire.

Une troisième variante du KILL SPOOL a été désignée par DEFONCEUR DE PLOMB SPOOL. Cette variante a engoufré la partie restante du corps de la tête de puits, et le scellement contre la partie du corps amincie et endommagée de la tête de puits, juste au-dessus de la partie inférieure du rebord restant le joint a pu être renforcé en le vissant à ce rebord restant, ou le deuxième rebord rabattu selon l'état de ce qui reste de la tête du puits. Le DEFONCEUR DE PLOMB a été monté sur plusieurs équipements de tête de puits endommagées, où le spool du tuyau avait sauté à moitié par les explosifs.

Des KILL SPOOLS ont été utilisés sur 35% des puits explosés. La plupart ont été montés sur des casing spools de 11 in. et 2.000 psi., et quelques-uns ont été installés sur des casingheads de 13 5/8 in. 2.000 psi. Rarement quand les têtes des tuyaux de 7 1/16 in., 2.000 psi près des 11 in., 2.000 psi quand les têtes des tuyaux étaient intacts.

Les stingers utilisés au KOWAIT ont été conçus par VETCO GRAY, et on débat en détail leur utilisation ailleurs dans où il y a de très fortes pressions.

EXTRAITS DE L'INVENTION CONCERNEE ET LA TRADUCTION LITTERALE DU PARAGRAPHE **CAPPING BLOWOUT** PAGE 76 DE **WORL OIL SPECIAL REPORT** DE MAI 92, RAPPORT DE **LARRY FLAK.**

INVENTION CONCERNEE

LE SYSTEME D'EXTINCTION DES PUITS SOUMIS A DE TRES FORTES PRESSIONS, L'INVENTION **PCT FR 92 00405** QUI A ETE DECLARE MEILLEUR SYSTEME ET UNE PREMIERE MONDIALE.

CAPPING BLOWOUTS — CONTROLE DE L'EXTINCTION

Il y a eu peu de changements radicaux dans les procédés et les équipements appliqués pour l'extinction des puits soumis à de fortes pressions. Au lieu de développements ça a été le résultat des raffinements des technologies existantes et qui sont évidents d'après les réponses que WORL OIL a reçues quand nous avions invité les responsables des sociétés industrielles sur les puits en contrôle pour décrire ce qu'il y a de nouveau à ce sujet.

Aussi bien qu'on s'était attendu les travaux d'extinction des puits au KUWAIT ont été le thème des conversations. Mais le plus mauvais au monde concernant le cauchemar du contrôle des puits a été la manipulation presque selon une habitude de la manière de l'usage des équipements aux- quels le rôle de base avait été prouvé de temps en temps depuis les premières extinctions. La différence significative a été l'immense dimension des travaux qui ont pourvu l'opportunité à partager les équipements et les connaissances, et d'établir les raffinements qui auraient pu prendre des années avant d'être accomplis dans les circonstances normales. Ci-après sont décrites les techniques des matériels qui selon les experts ont été les plus utiles.

EXTRAITS DES INVENTIONS CONCERNEES ET LA TRADUCTION LITTERALE DU PARAGRAPHE **F U T U R E S A P P L I C A T I O N S** PAGE 81 DE **W O R L O I L S P E C I A L R E P O R T**, DE MAI 1992, RAPPORT DE **L A R R Y F L A K .**

INVENTIONS CONCERNEES

LE SYSTEME DE BLOCAGE EST L'INVENTION **P C T F R 9 2 0 0 3 2 3** COMPORTANT LES PARTIES SUIVANTES:

i. LE SYSTEME D'OPPOSITION A LA PRESSION ET DE PLOMBAGE EN PLOMB, AGISSANT PAR EXTENSION A L'INTERIEUR DU PUITS, PLOMBANT AUSSI LES USURES.

ii. LE SYSTELE DE BLOCAGE PRINCIPAL COMPORTANT UN AXE CENTRAL CONIQUE SUR CETTE PARTIE ET UN CYLINDRE COMPORTANT A L'INTERIEUR UN FRAISAGE CONIQUE ET UNE FENTE LONGITUDINALE, AGISSANT PAR EXTENSION SIMULTANEMENT AVEC LE SYSTEME D'OPPOSITION A LA PRESSION SUR LA PAROI INTERIEURE DU PUITS, L'AXE CENTRAL CONIQUE AYANT, EXEMPLE 50 % DE PLUS DE DIAMETRE DE LA DIFFERENCE DES DIAMETRES INTERIEURS CONIQUES DES DEUX EXTREMITES DU CYLINDRE.

iii. LE SYSTEME DE CENTRAGE PAR LE PRINCIPE DU PANTOGRAPHE.

FUTURE APPLICATIONS — APPLICATIONS FUTURES

Quoique ce procédé de stinging a existé depuis des années, les récents raffinements l'ont fait le beaucoup plus pratique des moyens de contrôle des puits. Beaucoup d'accidents de pertes du contrôle de puits ont lieu en AMERIQUE du NORD chaque année résultant de ce que l'équipement tombe à l'intérieur ou qu'il est projecté du côté opposé, heurtant la partie supérieure de la tête de puits Habituellement, une rupture à la lieu en rabattant la valve principale. Ces circonstances sont idéales pour l'application du stinging, avec un coût très limité pour un équipement de blocage, ces situations ont pu être ramenées sous le contrôle en quelques heures.

EXTRAITS DES INVENTIONS CONCERNEES ET LA TRADUCTION LITTERALE DU PARAGRAPHE **TRASH PLUGGING** PAGE 81 DE **WORLD OIL SPECIAL REPORT** DE MAI 1992 RAPPORT DE **LARRY FLAK**

INVENTIONS CONCERNEES

LE KILL SPOOL EST L'INVENTION **PCT FR 92 00323** COMPORTANT LES PARTIES SUIVANTES :

i. LE SYSTEME D'OPPOSITION A LA PRESSION ET DE PLOMBAGE EN PLOMB, AGISSANT PAR EXTENSION A L'INTERIEUR DU PUITS PLOMBANT AUSSI LES USURES.

ii. LE SYSTEME DE BLOCAGE PRINCIPAL COMPORTANT UN AXE CENTRAL CONIQUE SUR CETTE PARTIE ET UN CYLINDRE COMPORTANT A L'INTERIEUR UN FRAISAGE CONIQUE ET UNE FENTE LONGITUDINALE, AGISSANT PAR EXTENSION SIMULTANEMENT AVEC LE SYSTEME D'OPPOSITION A LA PRESSION SUR LA PAROI INTERIEURE DU PUITS, L'AXE CENTRAL CONIQUE AYANT, EXEMPLE 50 % DE PLUS DE DIAMETRE DE LA DIFFERENCE DES DIAMETRES INTERIEURS CONIQUES DES DEUX EXTREMITES DU CYLINDRE.

iii. LE SYSTEME DE CENTRAGE PAR LE PRINCIPE DU PANTOGRAPHE.

TRASH PLUGGING — BOUCHON A BAS PRIX

Le bouchon à bas prix. L'aptitude conséquente fiable et sûre est le scellage entre le OD du stinger et l'ouverture de la tête du puits exceptionnellement irrégulière, aussi bien que les bouchons d'autres têtes de puits craquées et cassées fuyant au sol sont fondamentaux à l'universel usage du procédé stinging. Le bouchon à bas prix comportant une pompe est une variété de matériel à bouchonner à pris assez bas assurant son lancement dans tous les pays où la sortie du flux est vive. Quoique les balles de golf de scellage et des morceaux de latex et des matériaux de joint utilisés pour des applications spécifiques, le plus efficace des matériaux évidents a été des morceaux de cordes de polypropilène non-tressés nouées s'adaptant à la dimension apparente des rebords qui fuient. Les situations difficiles nécessitent de de nombreux efforts de diminution du volume du matériel éffectuant un scellage complet.

Le bouchon à bas prix est au lancement du projet et a été un beau cru, choisi selon le procédé du tatonnement, mais avec un continuel développement il est devenu un très sophistiqué, sûr et fiable mécanisme de blocage. Les têtes de puits qui existaient ne tiennent à aucune pression au pompage, à savoir que proportionnellement 8 à 10 bpm pourront être scellés à bas prix, aussi bien qu'il résiste à 2000 psi sans aucune fuite.

TRADUCTION LITTERALE DU PARAGRAPHE 2, PAGE 81 DE WORLD OIL SPECIAL REPORT DE MAI 1992, RAPPORT DE LARRY FLAK (CHIEF ENGINEER OGS ET OGE DRILLING), COORDINATEUR DES TRAVAUX D'EXTINCTION POUR KOWAIT OIL COMPANY DU 04.03.91 AU 19.11.91

INVENTION VOLEE

LE SYSTEME DE CENTRAGE COMPORTANT LE PRINCIPE DU PANTOGRAPHE

STINGER ASSEMBLY PARAGRAPHE 4 — L'ASSEMBLAGE DU STINGER PARAGRAPHE 4

Le stinger a été monté sur une grue hydraulique ayant plusieurs avantages de plus que le plus conventionnel des engins ATHEY. Pourvu d'un élément sensible pouvant se mouvoir dans six directions contrôlant l'assemblage du stinging l'orientation de la trajectoire avec précision a été possible, et une fois que le stinger a été engagé dans la tête du puits, l'ouverture pourrait être fraisée ou défoncée ouvre davantage par oscillation de l'assemblage. Le contrôle hydraulique de la pression descendante de plus de 16000 lb a été maîtrisé. L'assemblage avance selon un parcours conventionnel, et avec une complète harmonie, sans nécessiter aucun assemblage ou montage avant que le travail ait été commencé.

How well control techniques were refined in Kuwait

Larry Flak, Chief Engineer,
O'Brien-Goins-Simpson & Associates,
Houston

Retreating Iraqi soldiers detonated explosives placed on 749 wells in Kuwait, causing some 698 blowouts (excluding some minor blowouts in the Neutral Zone). This necessitated an unprecedented effort on the part of well control/firefighting companies and the service and supply firms that aided them. Some of this effort's success involved procedures and techniques developed during the course of actual well control operations in Kuwait. These included:

- **Cutting tool developments.** Some blowouts would have been vastly more difficult to control without the use of high pressure, abrasive jet cutters. These cutters also significantly improved work progress. Other cutting tools such as pneumatic casing cutters and thermal lances also proved their merit.
- **New kill spools** were developed that incorporated deformable lead seals.
- **Stingers** with varied and novel geometries were developed on site.
- **Fire extinguishing methods.** Over 90% of all fires were extinguished using only water and multiple, high-rate water monitors. Additionally, firefighting generally represented only a minor part of the total time spent controlling a blowout.

All of these developments were part of the normal course of refinement and innovation to be expected from the extraordinary group of oil field experts assembled in Kuwait. Thousands of proposals were submitted for controlling the blowouts, but none had any new merit. Ultimately, the key to success was that experienced oil field people got together, discussed the problems and were given a free hand to solve them.

HIGH PRESSURE, ABRASIVE JET CUTTERS

In the past, firefighters built abrasive cutters in the field from whatever was available. Standard triplex oil field cementing units were used to pump sand with fracturing gel at relatively low pressures (less than 7,500 psi) through these "nozzles." Cuts could not be controlled precisely, were slow and were incapable of penetrating multiple pipe strings. These systems could not make vertical or stripping cuts, which allow removal of outer cemented pipe without damage to the inner pipe string. Another previous method used swab trucks "sawing" with 9/16-in. swab line. This was an extremely slow process that could take days.

High pressure abrasive jet cutting systems were originally developed for industrial cutting and cleaning applications. Early oil field application involved severing jacket legs and conductors on offshore platforms. Two systems used in Kuwait were designed by both service companies and firefighters specifically for blowout control operations. The primary system was provided by the Harben Systems of the U.K. and operated in Kuwait in partnership with Hytorc Services of Dubai. The other system was from Halliburton Services.

The Hytorc-Harben Jet Edge device uses a 250-hp diesel engine to run hydraulically-powered, dual intensifier pumps delivering 3 to 4 gpm of filtered water at 32,000 to 34,000 psi. A garnet abrasive is added to the water at 1 lb per gal through a patented valve downstream of the pump and just upstream of a synthetic sapphire orifice. The garnet abrasive is accelerated to 4.5 times the speed of sound as it exits the nozzle. Water supply (500 gal), pump package, abrasive hopper and controls were all mounted on a single, 40-ft oil field float.

Fig. 1. This abrasive cutter has a single nozzle that travels 360° around an outer casing string. A hydraulically-powered tractor runs on a flexible stainless steel track mounted on a frame wrapped around and locked to casing or wellhead. There are some risks (re-ignition is the greatest) to the operators since they have to enter the cellar during cutter installation. After mounting, cutter is operated remotely. *Courtesy of Boots & Coots*

Fig. 2. A massive, 18¾-in., 10,000-psi by 26¾-in., 5,000-psi casing spool (and enclosed 13⅜, 10¾, 7¾ and 3½-in. tubulars) was cut in 4 hours using the Hytorc cutter.

Hytorc-Harben worked with firefighters, Oilfield Rental-Wellcat and ABB Vetco Gray to fabricate a horizontal cut off system that used a single nozzle conveyed 360° around an outer casing string by a hydraulically-powered tractor running on a flexible stainless steel track. Nozzle orientation could be varied to avoid cutting an inner pipe string. Track was mounted on a frame wrapped around and locked to casing or wellhead (Fig.

1). When cutting started, horizontal oil flow out of the cut indicated successful penetration and could be used to set required track speed.

A cutting team consisted of a Hytorc representative with an oil field background and a Harben engineer experienced in operating the pump and abrasive system. The cutter could be rigged up in 15 to 30 min and could horizontally cut 20, 13⅜, 9⅝ and 7-in. casing, plus 3½-in. tubing, with dual flow through the tubing annulus all at once in one to two hours. A massive, 18¾-in., 10,000-psi × 26¾-in., 5,000-psi casing spool (and enclosed 13⅜, 10¾, 7¾ and 3½-in. tubulars) was cut in 4 hours (Fig. 2). Generally, a cutting team made several cuts a day at multiple well sites. Some problems were experienced with high velocity gas flow in the production annulus when cutting tubing, and cuts could be made faster if pipe stings were all cemented. In both cases, relative jet stability was the cause.

There were some risks to the operators (re-ignition was the greatest) during installation of the cutter since they had to enter the cellar. After being mounted, the cutter was operated remotely. Some re-ignitions occurred days after the well had been extinguished. Hytorc-Harben operators used fire-retardant Nomex underwear and coveralls. Safety harnesses with tag lines attached were worn and a safety man was placed to pull operators clear of the well if necessary. Water monitors were in place with pumps running to provide a water curtain.

A cutting system developed for making vertical cuts used a nozzle oriented such that it would leave inner casing undamaged. This was required on some wells where cement was present within the annuli. Of great use was a wand cutter that could be used free-hand or mounted on a modified machine gun tripod to stabilize the wand. This was used to cut studs (less than 15 sec per stud) or trim away metal debris (Fig. 3). It was also used to cut windows that would allow the tubing string to be dropped and facilitate removal of a damaged tubing head. Ultimately there were five Hytorc-Harben cutter teams employed in Kuwait.

The first jet cutter arrived in Kuwait in mid-July, and as can be seen in Fig. 4, capping progress significantly improved from that point. Part of this improvement was due to arrival of some much-needed 'dozers, cranes and tracked backhoes, but a significant portion was due to the cutting system.

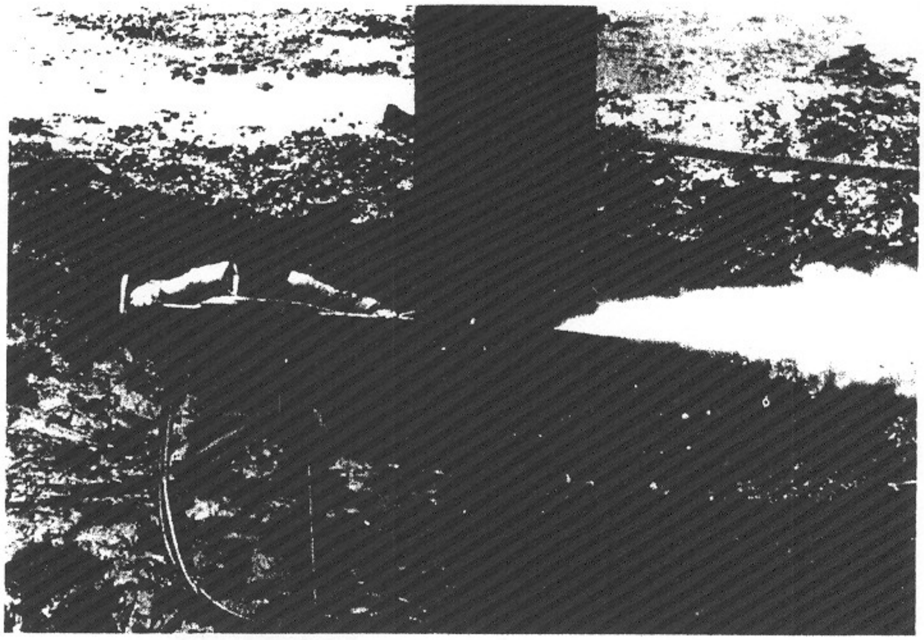


Fig. 3. A wand cutter, used free-hand or mounted on a modified machine gun tripod for stabilization, was used to cut studs (less than 15 sec per stud) or trim away metal debris. It was also used to cut windows that would allow the tubing string to be dropped and facilitate removal of a damaged tubing head. *Courtesy of Boots & Coots*

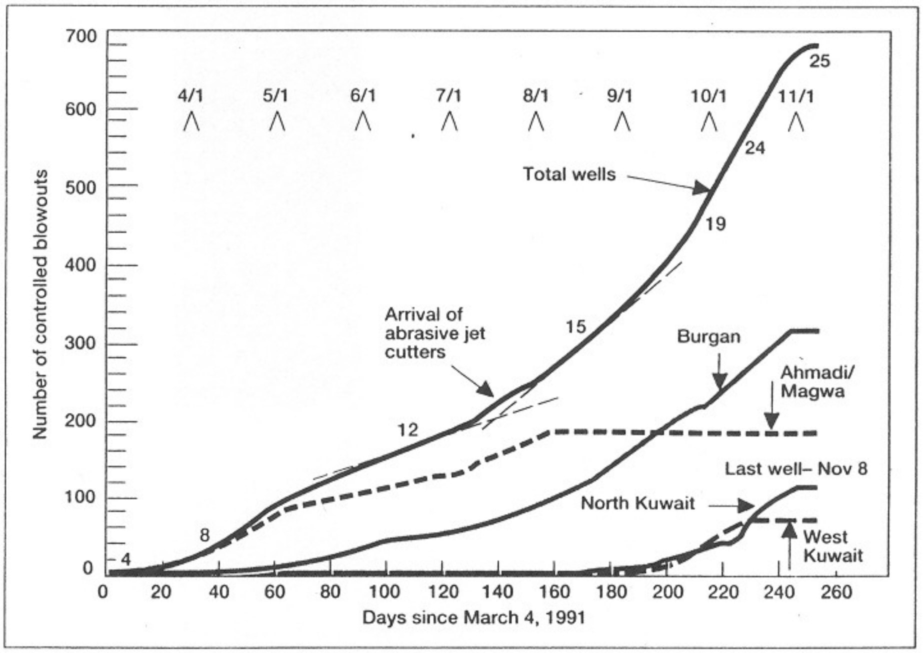


Fig. 4. The first jet cutters arrived in Kuwait in mid-July, and capping progress significantly improved from that point. A portion of this improvement was due to arrival of much-needed 'dozers, cranes and backhoes.

The Halliburton cutter and its use are discussed in detail elsewhere (see page 78). It was principally used on burning wells. Two of these systems were employed in Kuwait.

PNEUMATIC COLD CUTTER

The pneumatic cold cutter consists of knives that rotate around casing, taking a deeper cut each rotation (Fig. 5). Precise control of cut placement and depth is possible. These cutters are not new to the oil field (previous applications were in pipelining), but their application in Kuwait in combination with the abrasive jet cutters was new and facilitated application of both tools.

Precise control of the final cut to expose production casing was not possible with abrasive jet cutters. Generally, the final cut on 9⅝-in. would be made using the pneumatic cold cutter to expose 7-in. casing. On several

Fig. 5. The pneumatic cold cutter consists of knives that rotate around casing, making a deeper cut each rotation. Precise control of cut placement and depth is possible. Generally, the final cut on 9⅝-in. would be made using the pneumatic cold cutter to expose 7-in. casing. *Courtesy of Boots & Coots*

wells, it was possible to excavate around and expose the end of the shallow conductor, cut off 13⅜-in. casing below the conductor with the pneumatic cutter, and then remove both the cut-off piece of surface casing and conductor to expose 9⅝-in. casing. This eliminated the need for the abrasive cutter.

Over 12 cold cutters purchased from Porta-Lathe or Myoco were employed in Kuwait. A serviceman was present to assist firefighters in operating and maintaining these cutters, which were pooled in one location and pre-trimmed for various pipe sizes. Firefighters would check out a pre-trimmed cutter for a particular job and return it to the shop for reuse. A serviceman would assist firefighters in using the tool.

THERMAL LANCES

Thermal lances have been used for years in firefighting operations. Lances used in Kuwait consist of a 10-ft long, mild steel hollow tube packed with approximately 15 carbon rods (each rod has the diameter of a pencil lead). They are ignited with an arc welder and burn as oxygen flows inside a ½-in. steel tube and around the carbon rods. A pack-off holder at the end of the lance directs oxygen down the tube and around the rods. A standard bottle of oxygen would last for about 2½ lances. Thus, several bottles were manifolded together.

Typically, oxygen at 180 psi was used to optimize performance. Too high a pressure caused the lance to excessively splatter and too low a pressure reduced cutting effectiveness. A lance is capable of melting through 2 ft of concrete or 1 ft of steel. A 10-ft lance will burn down in about three minutes and will cut through any wellhead equipment and pipe in seconds. Lances were used primarily to facilitate placing a final well cap on controlled wells. Over 2,000 were consumed in Kuwait.

Safety Boss was the primary user of these lances. After killing a blowout, lances quickly cut away damaged wellhead and casing to expose production casing so that a slip-over and weld-on abandonment cap could be installed (Fig. 6). Generally, wells had been killed using a stinger and a more permanent well closure had to be applied. Capping teams followed well killing teams and installed these abandonment caps. Disadvantages to the lances are an ignition hazard and the requirement for a strong and skilled operator, who wore special fire suits and hoods for protection. Lances were used on some burning wells to clear debris that was interfering with kill plans.

EXPLOSIVES

Explosives have been used for many years to extinguish fires and to clear and cut debris from blowouts. Paul N. "Red" Adair developed and used shaped charges in the late 1930s. Premanufactured linear strip charges have been used to sever pipe, wellheads and BOPs. In Kuwait, linear shaped charges were used to cut multiple pipe strings and sever damaged wellhead equipment.

Red Adair Co., Boots & Coots, Cudd Pressure Control and Wild Well Control used explosives to clear coke, sever wellheads and extinguish fires. Wild Well Control was the primary user of linear shaped charges to cut casing. Three linear shaped charge sizes had been manufactured by Goex for firefighting operations, including 600-grain per ft RDX, 1,200-grain per ft RDX and 1.5-pound per ft (18-in. long) RDX severing charges. The 600 and 1,200-grain charges were molded into a copper liner that allowed charges to be bent around the circumference of casing. (The 1,200-grain charge would always cut the outer casing string, but could also perforate the inner casing string if pipes were not concentric. The 600-grain charge would generally cut only the outer casing string. On some heavier grade, outer pipes, the 1,200-grain charges could be used since there was little risk of perforating down to production casing. Large severing charges were used to remove damaged wellheads and debris. Generally, these shaped charges would re-ignite the well. Alternatively, burning wells could be extinguished.

The U.S. Army also worked with the firefighters, using 165-mm, low-velocity, 65-lb demolition rounds fired from a Combat Engineering Vehicle (CEV) to break up coke mounds. Coke is a concrete-hard mixture of melted

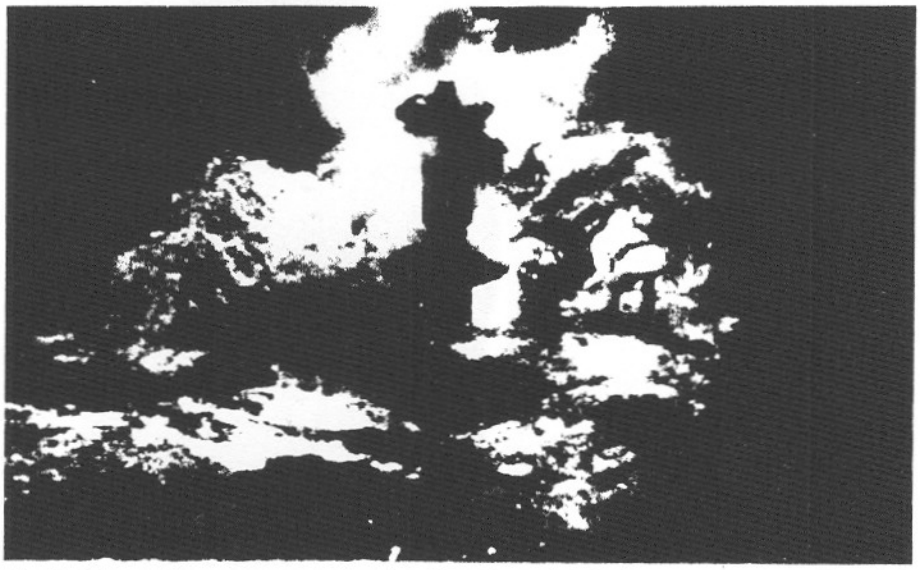


Fig. 6. Thermal lances are capable of melting through 2 ft of concrete or 1 ft of steel. A 10-ft lance will burn down in about three minutes and will cut through any wellhead equipment and pipe in seconds. Lances quickly cut away damaged wellhead and casing to expose production casing so that a slip-over and weld-on abandonment cap could be installed. *Courtesy of Safety Boss*

sand, carbon, salt and asphalt that built up around some wells preventing access. The CEV is a modified M-60 tank used by combat engineers to clear paths through enemy fortifications. Large coke deposits around three wells were demolished in this manner. Wells were selected if their field location provided a clear downrange.

The CEVs successfully fired at these mounds and broke up the coke to allow removal. The last shot at was a huge mound surrounding Burgan well 93 (over 15 ft high and 40 ft in diameter). Two CEVs volley fired 35 rounds at the mound, turning it to rubble. (No other target in the 30-year history of the CEV had ever been hit as many times.) Coke is porous and is capable of absorbing tremendous explosive energy. The Red Adair team working on the well was able to clear the fractured and broken coke in less than 3 hr, compared to the several days normally required to remove a mound of this size using conventional methods.

KILL SPOOLS AND STINGERS

ABB Vetco Gray managed the Kuwait Oil Co. machine shop in Ahmadi, and was able to develop custom capping heads and stinger geometries for specific applications, generally overnight with the "impossible" taking a few days. New developments were made in deformable lead seal kill spools. Most significant of these involved lead seals arranged to effect a seal between a kill spool and remaining wellhead (Fig. 7). These consisted of a lead seal mounted in a groove, machined into the kill spool flange face and designed to seal on a flange face between the bore and ring gasket groove, or alternately, in the ring groove. In many cases, deformation and/or cracking extended through the ring groove on a wellhead, requiring a seal to be located just outside of the wellhead bore but inside the ring groove.

A third kill spool design was termed a "lead smasher" spool. This design swallowed the body section of a remaining wellhead and sealed against the damaged wellhead's tapering body section just above the lower remaining flange. The seal could be energized by bolting to this remaining flange, or the next lower flange, depending on the condition of the remaining wellhead equipment. The lead smasher was used on severely damaged wellhead equipment where the casing spool had been blown in half by explosives.

Kill spools were used to cap 35% of the Kuwaiti blowouts. A majority were installed on 11-in., 2,000-psi casing spools, and some were installed on $13\frac{5}{8}$-in., 2,000-psi casingheads. Rarely were the $7\frac{1}{16}$-in., 2,000-psi by 11-in., 2,000-psi tubingheads intact. Generally 10 or 12-in. ANSI ball valves were used above the spools, and the spools had two, 2-in. LP outlets.

Stingers used in Kuwait were designed by Vetco Gray and their use is discussed in detail elsewhere in this issue (see page 80).

CAPPING BOPS

Oilfield Rental's Wellcat Division well control equipment specialists did a phenomenal job of managing the large inventory of well capping BOPs, spools, DSAs and adapters available to the firefighters. In addition to custom fabrication, they prepared and helped install capping BOPs.

Two basic types of BOP configurations were used. In northern and western Kuwait and on deep Marrat wells, good flanges generally remained below the tubinghead or tubing bonnet. A capping stack consisting of a single blind ram mounted above a drilling spool, which matched the remaining flange, was used. On Marrat wells, a $7\frac{1}{16}$-in., 15,000-psi BOP and spool were used to match the flange size on the tubinghead. On lower pressured wells, a 11-in., 5,000-psi blind ram was used above an 11-in.(2,000, 3,000 or 5,000-psi) drilling spool to match up with a remaining casing spool flange. There was little new development with these tools.

The secondary method used on 10% of the larger blowouts utilized a capping stack that is described in detail beginning on page 76.

INFLATABLE PACKERS

Baker Service Tools provided several sizes ($1\frac{3}{4}$, $2\frac{1}{8}$ and $3\frac{3}{8}$-in. diameters) of inflatable packers. These packers were stung into tubing or casing and inflated to shut off flow. Application was limited since tubulars near surface were commonly excessively deformed and would seldom allow full entry of the packer elements. Packers were more commonly used to secure a well previously killed with a stinger until an abandonment cap could be installed. **WO**

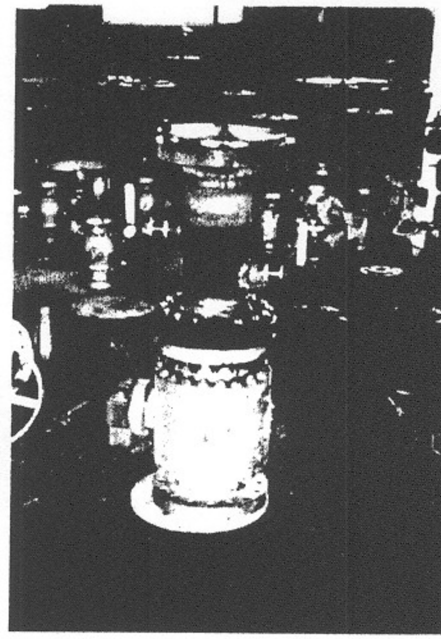
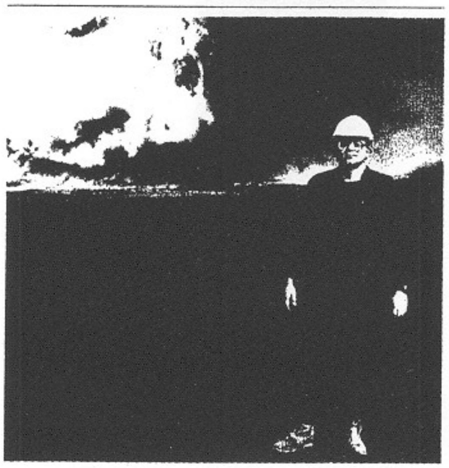


Fig. 7. Lead seals were used to seal between a kill spool and remaining wellhead. These consisted of a lead ring, which was mounted in a groove machined into the kill spool flange face and designed to seal on a flange face between the bore and ring gasket groove, or alternately, in the ring groove. In many cases, deformation and/or cracking extended through the ring groove on a wellhead, requiring a seal just outside of the wellhead bore but inside the ring groove. *Courtesy of Dave Wilson, ABB Vetco Gray*



The author

Larry H. Flak is chief engineer for O'Brien-Goins-Simpson & Associates (OGS) and OGE Drilling and was firefighting coordinator for Kuwait Oil Company (KOC). He began work in Houston with KOC officials in October 1990, arrived in Kuwait on March 4, 1991, and returned to Houston on November 19, 1991. Work consisted of planning and contracting services for the blowouts. Mr. Flak's previous experience is worldwide in well control, drilling and completion engineering. He joined OGS in 1980 after having worked for ARCO. Mr. Flak graduated with a BS degree in petroleum engineering from Texas A&M University in 1977, is a member of SPE and is a prior author for World Oil *and SPE. He is currently working on a book entitled* Hell On Earth—Story Of Kuwait's Fires.

Capping blowouts: Tricks of the trade

There have been few radical changes in the procedures and equipment used for controlling wild wells. Instead, most developments are the result of refinements to existing technology. This was evident from the response *World Oil* received when we invited the industry's authorities on well control to describe what's new on this subject.

As might be expected, well control operations in Kuwait were the leading topic of discussion. But ironically, the world's worst well control nightmare was handled in an almost routine manner using equipment whose basic function had been proven time after time on earlier blowouts. The significant difference was the immense size of the job, which provided an opportunity to share equipment and resources and institute refinements that would have taken years to accomplish under "normal" circumstances. Following are the techniques and tools these experts say they benefited from the most.

Capping assembly answers shortage of wellhead equipment

Boots & Coots, Inc., Houston

Having been involved in contingency planning by Kuwait Oil Company, Boots & Coots knew that there would be severe damage to existing wellhead equipment and that a large number of wellheads would have to be removed. And with an anticipated shortage of wellhead equipment in Kuwait, the logical solution to the problem was to utilize a technique that solved a similar problem when controlling a blowout in Lake Maracaibo, Venezuela, in 1986.

The blowout, well SLB 54X, was capped in 85 ft of water using a BOP stack equipped with inverted pipe rams and slip rams to achieve a temporary tie-back. Due to the possibility of shut-in pressures in excess of 10,000 psi, a snubbing unit was rigged up after the BOP stack was installed. Next, well flow was routed through the diverter lines and drill pipe was successfully tied back to surface, allowing well to be killed from the bottom.[1]

The procedure applied during the Kuwaiti well control operations is summarized in the following photo story.

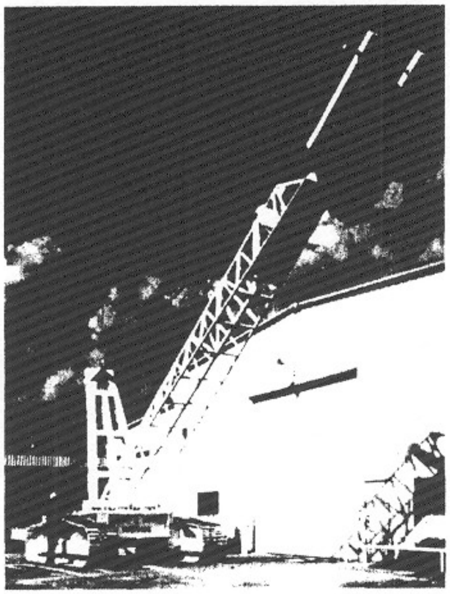
[1] From a paper presented to the SPE Conference, Dallas, Texas, 1987, which won the special Meritorious Award for Engineering Innovation.

After excavating around remaining wellhead, it is cut off, in this case using a Hytorc cutter as shown under the baseplate. The cutter severed all pipe strings (22, 13⅜, 9⅝ and 7-in. casing and 3½-in. tubing) with one pass in about 1½ hours.

Coke build-up is removed using a rake on an Athey wagon boom to expose wellhead. To achieve vertical flow, wellhead is removed by pulling it off using rake or cutting with sandline, explosives, Halliburton abrasive cutter, etc. Once vertical flow is achieved, ground fires could be extinguished or would simply go out due to lack of fuel source. Also, water used to cool firefighters and equipment would run to low spots where ground fires were concentrated and extinguish them. Wellhead fire is extinguished using water (or explosives as needed) and the surrounding area is cooled to prevent flash-backs (re-ignition).

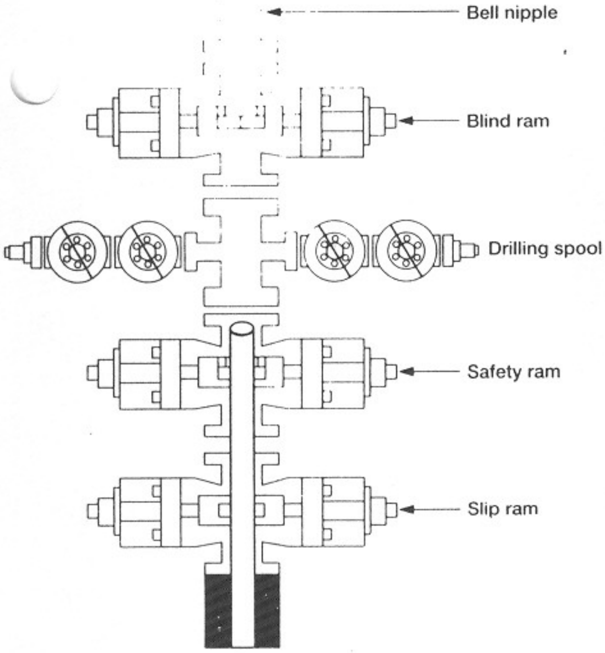
A mechanical cut is made under conductor pipe using a pneumatic air cutter. For this particular well, there was no cement between the 13⅜ and 9⅝-in. casing, thus allowing conductor pipe and the 13⅜ section to be removed by sliding it over the top of the 9⅝ and out through the flow.

Once 9⅝ is exposed, three cuts of approximately 16 in. each are made using pneumatic air cutter to expose 48 in. of 7-in. casing. A brass hammer was used to jar the 9⅝-in. casing and fracture cement between it and the 7-in casing to facilitate removal of the 9⅝. With 48 in. of 7-in. casing exposed, the well is ready for capping.

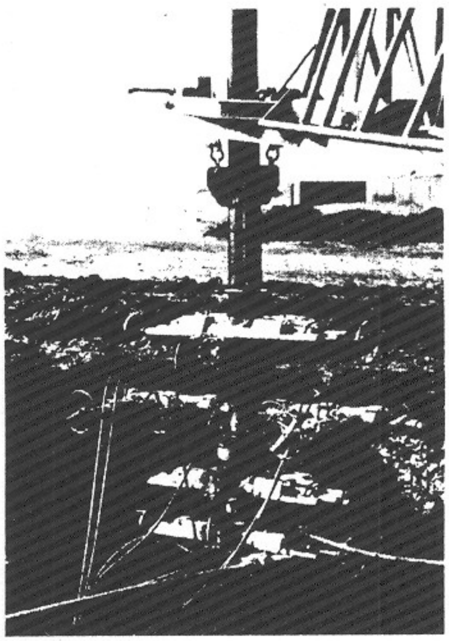


This heavy-duty Athey wagon, nicknamed the Tushhog, has an independent winch-package and hydraulic power source that allows firefighters to manipulate the capping assembly from a location behind the heat protection shield on a dozer blade. The unit's heavy-duty tracks and boom can be detached easily for air freighting by removing drive pins.

The capping stack is connected to the Athey wagon boom and moved into position in line with the well. A skirt and guide assembly attached to the bottom of the BOP keeps the stack from moving to either side or past the 7-in. casing. No snub lines were needed due to the weight of stack (25,000 to 30,000 lb), which is dependent upon size and pressure rating. A joint of tubing is used to connect the BOP stack to Athey wagon base and stabilize stack movement, while allowing some flexibility for positioning. BOP stack is positioned approximately 6 in. above top of casing and backed through the flow until casing touches against skirt on bottom of BOP. At this point (shown in photo), all flow is going through the BOP assembly as it is lowered over the 7-in. The guide assembly can now be removed.



The capping assembly used in the procedure described here consisted of (from top to bottom): • lift-nipple to convey well flow high above ground level, • blind rams for closing well in, • kill spool with hydraulic and manually-operated valves for pumping kill fluids, • inverted pipe rams to achieve a pack-off on 7-in. casing, • inverted slip rams to connect stack to 7-in. casing. (7-in. slip rams and pipe rams act as temporary wellhead.)



The capping assembly is lowered to the top of 9⅝-in., swallowing 48 in. of 7-in. casing. Top of 7-in. will be located just below valving area of the kill spool. Inverted pipe rams and the 7-in. slip rams are closed and locked, connecting the capping assembly to the 7-in. casing. Pump lines are connected and tested before closing well in. The well can now be killed. Due to the nature of the annular dual completions in these wells, the stack will be left in place for a few days of lubricating (bleed off pressure that may have built up and circulate more kill fluid as needed) while another well is being prepared. After removing BOP stack, a 7-in. socket-weld flange and 3,000-psi ball valve are installed. The well is temporarily secure and can be put back on production as equipment becomes available.

Abrasive cutters accelerate well capping procedure

Red Adair Company, Houston

Perhaps the most significant refinement to emerge from the efforts in Kuwait, according to just about all the well control teams that worked there, was the use of two versions of high-pressure abrasive cutters. These tools produced a noticeable increase in the rate at which wells were capped (see related article, page 72) and added to personnel safety. One of these tools, which was provided by Halliburton Services, was used extensively by the Red Adair Company, and is described in this section.

The overall concept is not truly new, since in the past, firefighters used abrasive cutters rigged up at the wellsite utilizing a bit nozzle or choke bean. Relatively low pressures (less than 5,000 psi) were applied through standard triplex oil field cementing units to pump 20/40 Ottawa sand carried by gelled water. Cutters were either manually positioned or mounted on the end of an Athey wagon boom, which was maneuvered by tractor, and were difficult to hold in the proper position. As a result; cuts could not be controlled precisely, were slow and incapable of severing multiple pipe strings.

Other alternatives to the abrasive cutters (particularly on burning wells) that have been used in the past included the use of swab line (9/16-in. line run against the wellhead between two swab trucks) to make a saw cut, or shaped charges. The swab line "saw" is extremely slow and the process can take days. Explosives are somewhat faster, requiring from one half to a full day (for set-up and charge placement), but often damage the wellhead, which can lead to more delay.

The Halliburton cutter system (Fig. 1) used in Kuwait was made possible by the development of a linear actuator (Fig. 2) that could move a nozzle in either direction precisely along the same line at a controlled rate. It also had to be mechanically rugged enough and heat resistant to function after being positioned in or near a burning wellstream.

The primary advantage of this system was that it could be remotely posi-

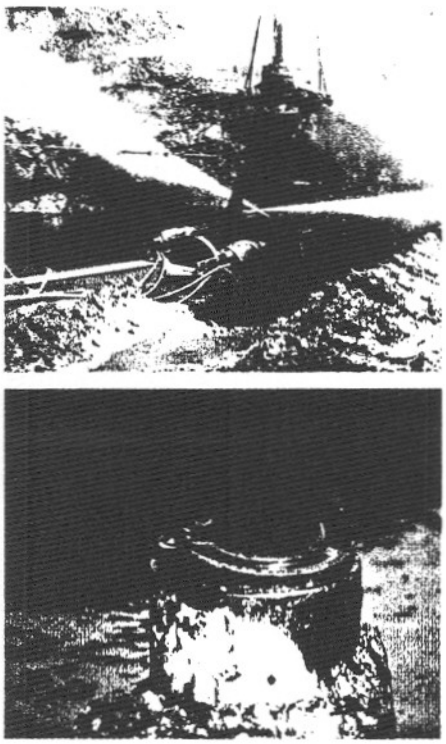


Fig. 1. The twin-nozzle abrasive jet cutter's primary advantage was its remote positioning and operating capabilities. This allowed wellhead equipment to be severed from burning wells and precluded the need for personnel to enter oil-flooded cellars (top photo). After cuts were made, wells were killed using stingers or capped using several different types of capping assemblies. Lower photo shows flow out of 7-in. casing that is being restricted by tubing, which fell downhole after being cut.

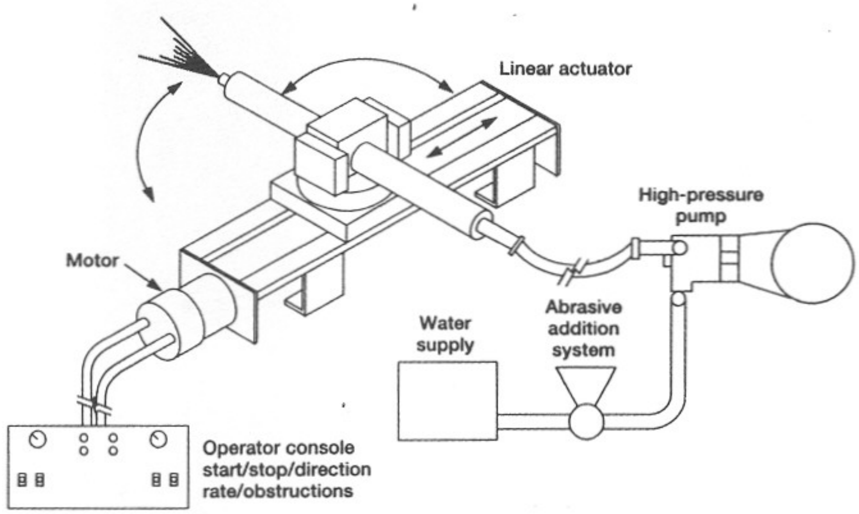


Fig. 2. A key component of the Halliburton jet cutter was its linear actuator, which was used to precisely guide the nozzles. At a remote operator's console, controls included stop and start, direction and rate.

Fig. 3. Pumping equipment for operating this abrasive jet cutting system is massive, but common to oil fields all over the world.

tioned for a cut on burning wells or those with a high risk of re-ignition (this eliminated the necessity of exposing personnel to the dangers of entering flooded cellars to set up or operate cutting equipment, which other techniques required). Cuts were also made with the tools completely submerged and positioned by "feel" (some cellars originally full of spilled oil were displaced with water to prevent re-ignition).

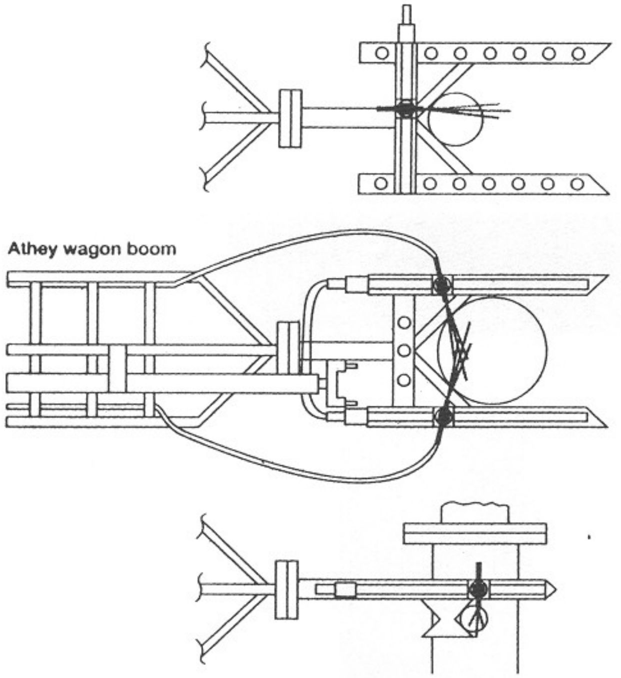


Fig. 4. The jet cutter could be rigged in three basic configurations, including a single horizontal nozzle (top), dual horizontal nozzles (middle) and a single vertical nozzle (bottom), which was the method typically used to remove wellhead wing valves.

Fig. 5. Example of precision cut made on a wellhead flange. The flange was actually split in half, and the section remaining on the well was used to install a capping assembly. After the cut was made, well control personnel simply drove the severed bolts from the bottom half of the flange and threaded new bolts through these holes to connect the new head.

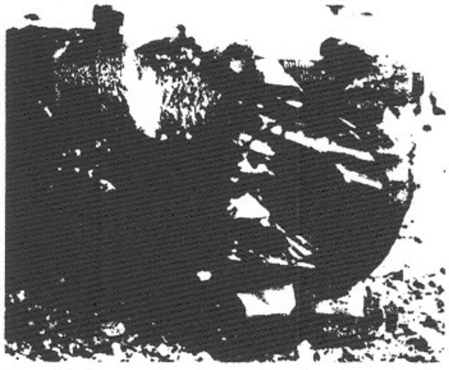


Fig. 6. Example of a vertical cut made to remove a wing valve.

The large amount of equipment required for this system (which approaches that of a small frac job, Fig. 3) could be considered a disadvantage if the remote positioning capability is not needed. Included were an Athey wagon-mounted cutter, a bulldozer, two HT-400/16V diesel pumping units, sand proportioner, sand truck, temporary water tanks and, for some types of cuts, an HT-1000 intensifier unit. However, these components are common to service operations, oil field rugged and relatively "weevil-proof," an important consideration in remote, difficult operations. Halliburton is justifiably proud of the fact that it did not have a single vehicle accident or injury during the entire Kuwaiti operation.

The Halliburton abrasive cutter system was typically set up with two linear actuators mounted (one on each side) on a U-shaped fixture that attached to the Athey wagon boom (Fig. 4). Each nozzle travels independently, but they are normally moved at the same speed. Each can be stopped or started individually at any time during the cut and either will stop automatically if it is obstructed.

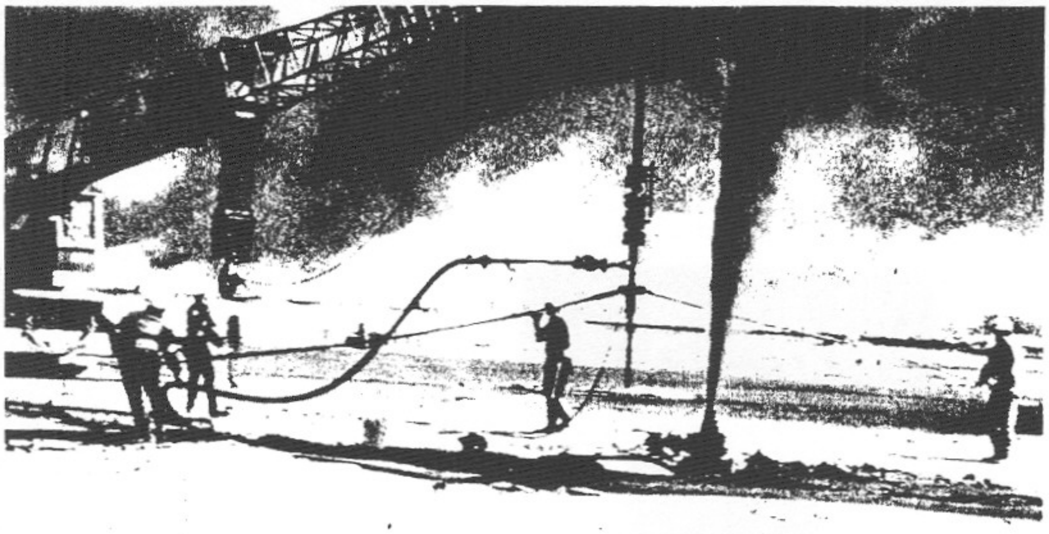
Jetting is typically done at transverse rates of about ½ in. per min, when cutting large diameter targets. Submerged cuts require about twice as much time. Actual cutting rates are determined by the specifics of target materials, nozzle diameter, pressure and abrasive type. Maximum pumping pressure used was 14,000 psi, and the average was about 11,000 psi. A better perspective is that these pressures deliver abrasive particles to the target at velocities ranging from 1,000 to 1,200 ft per sec. Sand was the common abrasive, but higher density and harder abrasives may be used in special cases. Heavy, deep penetration cuts across flowing streams, where positioning was difficult and allowances for error had to be large, were made with nozzles that required up to 550 hhp each.

In Kuwait, the heaviest cut made was through a 24-in. OD x 13-in. ID flange (Fig. 5), which is about equivalent to cutting a pipe with a 5½-in. wall thickness. This cut took 119 min since two passes were made to ensure the flange was completely severed. The average diameter cut was in the range of 20 in.

A single jet was often used instead of the twin jet configuration to make smaller cuts such as severing wing valves (Fig. 6). Usually targets of less than 10 in. in diameter were cut with single nozzles.

Well control specialists say the stability provided by pushing the cutter fixture solidly against the wellhead was a key factor in the success of this cutting system. Even on the "stiff" booms of these heavy-duty Athey wagons, the free boom tip vibrates and sways noticeably (which reduces cutting efficiency) unless the boom is steadied in some manner. The U-shaped "throat" of the cutter fixture also centers the nozzles on the target.

In addition to removal of damaged wellhead components prior to capping operations, future applications for this system could include debris clearing work on blowouts that involve drilling rigs or production structures. Abrasive jetting is also a good method of cutting through steel reinforced concrete structures found in cellars and some production facilities. *Continued*



A stinger mounted on a 90-ton mobile hydraulic crane provided several advantages, including a sensitive and articulate six-way control of the stinging assembly and pin-point stabbing accuracy. Once the stinger was engaged inside the wellhead, the opening could be reamed or swaged open further by oscillating the assembly. A controlled, hydraulic down force of up to 16,000 lb could be applied as required. Unit travels at conventional road speeds as a complete package.

Stinging procedures allow rapid well control

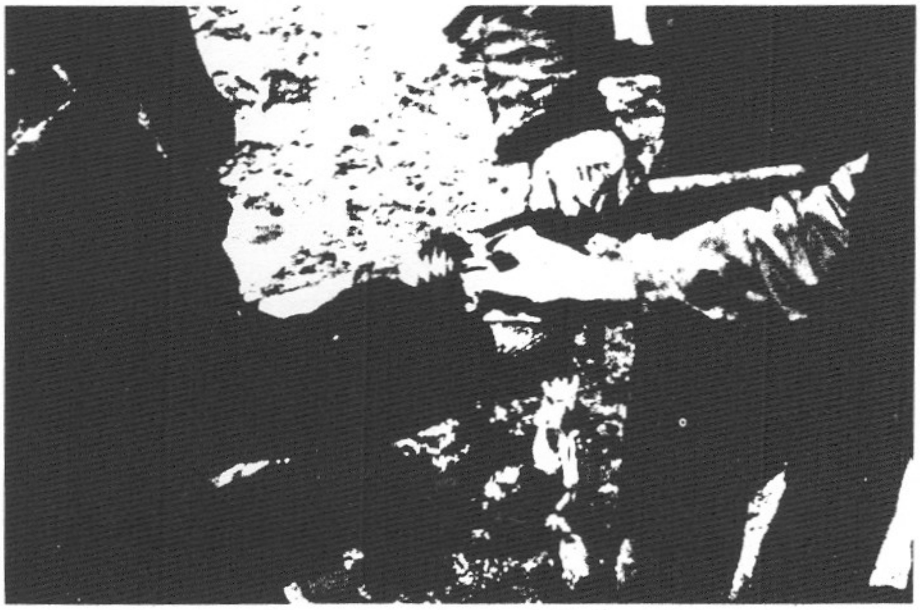
Safety Boss, Calgary, Alta., Canada

About one half of the wells capped by Safety Boss in Kuwait were killed using a stinging procedure. In its most basic form, this involved inserting a hollow-tipped stinger into a wellhead opening; then while holding it in place, a kill fluid was forced down through the well's tubulars. When the technique was possible, it was by far the fastest and safest procedure since it was not necessary to remove damaged wellhead equipment before killing the well.

One of the most dangerous and difficult tasks in well control is the removal of badly damaged wellheads so that a kill spool or BOP can be installed. In most cases, the fire was only recently extinguished and the immediate area was a hot bed of coke, metal, rock and other potential sources of re-ignition, which did occur at times when crews were working on wellheads. Only the constant vigilance of personnel manning water monitors and rescue people who were on standby prevented serious injury. Wellheads were badly fractured, spewing oil and gas in many directions, and thus hindering access and making working conditions extreme. Studs and nuts were badly deformed and usually had to be split or cut. Frequently, when one section was removed, it revealed a warped, cracked or otherwise unusable mating flange below it, which necessitated further removal.

Stinger assembly. Instead of an Athey wagon, Safety Boss mounted a stinger on the head of the jib section of a 90-ton mobile hydraulic crane. The main body of the stinger was a complete 4-in. drill collar. On top of the stinger was a flange that contained a 45° ell to deflect well flow away from the crane. About 10 ft down from the top of the drill collar, a pinned swivelling saddle clamp held the assembly to the head of the jib. A 3-in., full opening valve was flanged to the bottom of the collar (about 20 ft below the clamp). Continuing further down the assembly was a tee with a 3-in. valve on the side outlet followed by a change-over to accommodate the various stingers. On the exterior of the change-over were lugs for attaching snub-down equipment.

The procedure was to stab the stinger into the wellhead with the upper valve open and the side outlet closed, but completely connected via a rubber shock hose to the pumping units. Once the stinger was situated in the best sealing position, the side outlet valve was opened and the upper valve closed. If leak-off was excessive



A variety of plugging materials were pumped to plug leak-off areas between the stinger and wellhead ID. Although golf balls, perf sealers and chunks of rubber and gasket material were used for specific applications, the main and most universally effective material used was unbraided rope sections knotted to fit the apparent size of leak outlets trash would be pumped to seal off between the stinger and wellhead. If the stinger demonstrated hydraulic lift, a snub-down bridle was rigged up to hold it in place before pumping began.

A wide variety of stinger tips was necessary, with sizes ranging from 1-in. through 9⅝-in. Long tapers and mushroom type heads were used to control penetration depth. Many wellheads were crushed or pinched by the explosive forces directed from two opposing sides of the wellheads when they were blown by the Iraqis. These required an assortment of elliptical, oval and other types of flattened styles of stinger tips. In the early stages, a machine shop supervisor was frequently brought out to location to measure the irregular openings so that the shop could build the appropriate tip overnight for use the next day.

A stinger mounted on a hydraulic crane had several advantages over the more conventional Athey wagon. It provided a sensitive and articulate six-way control of the stinging assembly. Pin-point stabbing accuracy was possible, and once the stinger was engaged inside the wellhead, the opening could be reamed or swaged open further by oscillating the assembly. A controlled, hydraulic down force of up to 16,000 lb could be applied as required. The unit traveled at conventional road speeds as a complete package, without any need of assembly or rig-up at the location before work was begun.

Trash plugging. The ability to consistently and reliably seal between the stinger's OD and the exceptionally irregular wellhead openings, as well as plug off other cracked and fractured wellhead leak-off areas was fundamental to the widespread use of the stinging procedure. Trash plugging involved pumping a variety of plugging materials at rates low enough to ensure that leak-off areas were the main source of outlet flow. Although golf balls, perf sealers and chunks of rubber and gasket material were used for specific applications, the main and most universally effective material used was unbraided polypropylene rope sections knotted to fit the apparent size of leak outlets. Persistent situations required multiple slugs of diminishing size material to effect a complete seal. Trash plugging at the start of the project was a fairly crude trial and error procedure, but through continual development, it became a very sophisticated and reliable sealing mechanism. Wellheads that at the outset would not hold any pressure at pump rates of 8 to 10 bpm could be sealed with trash so that they would hold 2,000 psi without leaking.

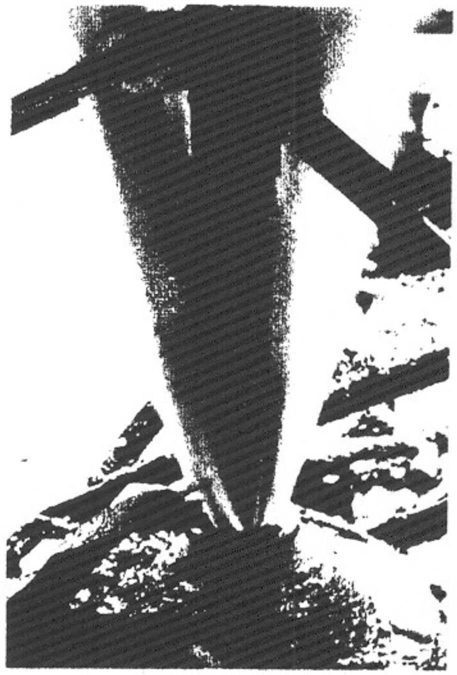
Stinging procedure refinements. Many wells in Burgan field were dual completions with one zone producing through tubing and the other up the annulus. Therefore a stinging application still left the annulus producing. The most obvious extension was to horizontally sting the annulus opening with a stinger mounted on the bucket of a trackhoe. This was done successfully on a few occasions, but usually if one annulus valve was damaged, they both were. This situation was handled by first stinging and killing the tubing and then rigging up a perforating assembly on top of the stinger and running through it to perforate the tubing opposite the annulus producing zone and circulating it dead by pumping down the stinger. Another extended development was running Baker inflatable packers on the end of the stinger assembly. Once positioned below the damaged area, the element could be inflated by pumping a small amount of fluid. After maximum inflation occurred, continued pumping would increase the pressure until a preset plug would shear out the bottom of the packer, allowing access through to the tubing. The small running diameter, as low as 1¾ in., compared to the large setting diameters, as well as the tough steel outer element shell, made these packers a preferred choice when it was possible to get them into the wellhead.

Future applications. Although this stinging procedure has existed for years, recent refinements make it a much more practical well control measure. Many incidents of lost well control occur in North America every year as a result of equipment running into, or otherwise, knocking off the upper portion of a wellhead. Usually, a break occurs at the bottom of the lower master valve. These circumstances are ideal for stinging applications, and with a very limited amount of standby equipment, these situations could be brought back under control in a matter of a few hours.

EXTINGUISHING FIRES USING DRY CHEMICALS

Before the Kuwait blowouts, dry chemicals had not been used extensively in extinguishing large blowout fires. Usually when water was insufficient to handle a job, explosives were used to snuff the flames.

However, Safety Boss has not used explosives for at least 15 years, preferring instead to use dry chemicals whenever water was ineffective in controlling fires. The company's dry chemical systems were used to control all sizes of fires in Kuwait.



Closer view of the stinging assembly being inserted into a wellhead shows the change-over that accommodates various stingers. Lugs were mounted to the change-over for attaching snub-down equipment.

These systems, which handled fires associated with wells producing up to 50,000 bopd, propel a high pressure stream of potassium bicarbonate into the source of the fire. Nitrogen propels the siliconized dry chemical powder, which when sprayed, behaves much like a liquid. In Kuwait, three skid-mounted dry chemical units, each with a discharge rate of 200 lb of dry chemical per second, were used. And unlike what sometimes happens with explosives, "you don't blow the end off your Athey wagon when you use them."

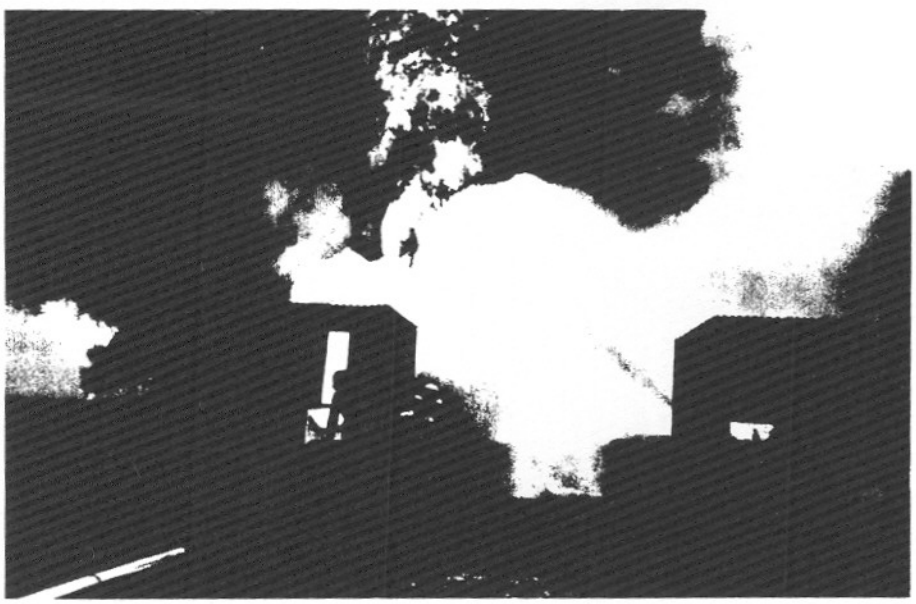
Kuwait provides ultimate test of refined firefighting equipment

Neal Adams Firefighters, Inc.,
Houston

Until recently, basic onshore blowout firefighting equipment has seen little change since its inception about fifty years ago. But when the Kuwaiti blowouts made the network news, all sorts of "unique" devices and procedures began popping up. Most of these never got past the idea stage, but some developments, which had been conceived (and successfully tested) before Kuwait, began to see heightened attention because of all the interest in this "once in a lifetime situation." Two developments of this type are a heavy duty Athey wagon and a high efficiency firewater pumping system that were put together by Neal Adams Firefighters.

Athey wagon. This tracked vehicle with movable boom is generally maneuvered and operated using a large bulldozer such as a Caterpillar D-8. Various implements are attached to the end of the boom to lift equipment, snag and remove obstructions and perform other firefighting and capping tasks. A new wagon was designed to make more efficient use of materials to achieve increased strength, rigidity and lifting capacity without adding redundant sophistication. Quick assembly and disassembly was another key requirement.

A new Athey wagon design has a square boom that is 50% stronger laterally and 120% stronger vertically than triangular booms, even while using similarly-sized longitudinal members. This allows the boom to withstand high temperatures and physical abuse without significant damage.



This firewater system included two 2,400-gpm pumps that cost less than a single 4,000-gpm unit, which has been the industry standard in the past. Large diameter aluminum piping (visible at lower left of photo) is used to reduce pressure losses and facilitate hook-ups (a 20-ft joint can be carried by one man). Piping system's snap-lock connections can tolerate large misalignments and assemble quickly.

The boom and lifting tackle were designed for a 25,000-lb working lift capacity, which would handle an 11-in. capping stack. The quad sheave lifting blocks provide a 9-line string-up, which exceeds these lift requirements and allows precise boom adjustment.

Conventional Athey wagon booms are triangular, whereas this unit has a square boom that is 50% stronger laterally and 120% stronger vertically, even while using similarly-sized longitudinal members. This translates into less twisting, flexing and down time for repairs, and allows the boom to withstand high temperatures and long periods of physical abuse.

Rather than using an independent hydraulic system, blocks are reeved with line that runs from the bulldozer's hydraulically-powered rear winch, which is enclosed inside the bulldozer body and protected from heat exposure (which will damage exposed hoses and other components). The wagon has a unitized configuration with built-in counterweights and improved, heavy duty tracks. The exterior is sealed, eliminating low spots that can fill up with oil, well debris or trash.

All wagon connections are pinned rather than flanged or welded. This greatly speeds boom assembly and the change-out of implements attached to its tip. The boom itself uses only four pins while implements are connected using a combination of three or more (up to six) pins.

The firewater pumping system consists of one or more pumps, suction and discharge lines, fire monitors and fire hoses. Industry standard systems typically have a large, 4,000-gpm pump with multiple, small diameter suction hoses and a pump discharge outlet that is sometimes swaged down directly at the discharge to a smaller flowline or manifold. This manifold is usually connected by hoses to welded steel lines that are fabricated on site and lead to the vicinity of the fire where aluminum piping is used to run the remaining short distance to the fire monitors.

Systems provided by Adams in Kuwait were intended to provide more efficiency and versatility. Design criteria included rates of 4,000 gpm, in excess of 300 ft of head with minimum pressure losses. Equipment consists of transportable pumps and lightweight, quick assembly piping. Individual pumping units have a 2,400-gpm capacity with 360 ft of head. Each is mounted on a unitized skid that included a fuel tank in its base and a heavy, pipe-protected structure. Skids weigh 5,000 lb and may be handled by a 6,000-lb capacity (or larger) forklift, which eliminates the need for a crane. Two units are used to achieve the 4,000 gpm industry standard while providing an extra margin of safety—if one pump goes down, the other is still available to produce 2,400 gpm of flow for protecting personnel and equipment near the fire, allowing them to retreat under cover of a water spray. Combined cost of the two 2,400-gpm pumps is less than that for a single 4,000-gpm unit.

Each pump has a single, easy-tq-handle 8-in. suction hose that makes up to the pump using a two-handle, snap-lock connection. Discharge piping is connected directly to the 5-in. pump discharge using a 5-by-8-in. swage. Large diameter (8-in.) aluminum piping is used to reduce pressure losses and facilitate hook-ups (a 20-ft joint of aluminum pipe can be carried by one man). Snap-lock connections, which can tolerate large misalignments and assemble quicker than welded, grooved or hammer union couplings, are also used.

The 8-in. line runs directly from the pump to the vicinity of the fire monitors where two, 6-in. lines branch off to two monitors. Final connection to the monitors are made with 6-in. flexible rubber hose.

Experience in Kuwait demonstrated that the system could be rigged up at a blowout, used to extinguish the fire and then rigged down and moved to another location in less than one day.

Regional equipment depots would speed future efforts

Abel Engineering/Well Control Co., Houston

Before Kuwait, an oil well fire or blowout was rightfully treated as a single project with unique facets. Equipment used to control the blowout often was discarded after the event on the premise that it would never be used again. But in Kuwait, project engineering was an important factor in completing the task in a much shorter time than predicted. The necessary goods, materials and services (ranging from firewater supply to sandwiches) were made available to the firefighting crews so that they could perform their job without delay. Material for capping wells was made available when needed and a system to share special tools and services was enacted.

One might think that future events cannot possibly gain from this experience since it is not feasible to provide similar project support to single events. However, the Kuwait fires were dealt with quickly because fire-fighting teams did not have to "re-invent the wheel" for each well; equipment was simply moved to the next location. After a few moves, the process of mobilization and demobilization became extremely efficient. The most important aspect that set Kuwait apart from past events was that well control equipment was used repeatedly. Then, the obvious question is why can't this be done on future events?

A risk management plan. If the oil industry would make well control precautions similar to those it has implemented for oil spills along the U.S. Gulf Coast, future blowouts could be dealt with quicker and at less cost.

The central idea is that most of the equipment and personnel necessary to control a blowout will be located in strategic sites around the world and kept ready for immediate deployment. Each site would be funded and governed by a cooperative of operators active in the region. A contractor would manage, staff and operate each regional location. A database containing equipment and vendor services applicable to most blowout scenarios would be maintained to assist management in locating the wide variety of items necessary for controlling a well. Equipment housed at each location would be designed and fabricated so that minimal rig up time is required when it is deployed. Four regions have been proposed for these cooperative sites:

- N. and S. America—Houston
- Europe—Aberdeen or Stavanger
- Middle East—Abu Dhabi
- Far East—Singapore or Indonesia.

At each of these sites, cooperative members would have the following at their immediate disposal:

- Inventory of special tools, including capping assemblies, hydrocutting tools, firewater systems, Athey wagons, etc., with the capability of handling three blowouts simultaneously
- Database for locating equipment and services such as exotic kill fluids
- Regional blowout contingency plan that details management organization, equipment specifications, pump schedules, etc.
- Staff composed of equipment operators, project managers, intervention teams, capping specialists, etc.

Obvious benefits of such a plan include immediate response to an incident and a comprehensive package of equipment and expertise at a considerably lower cost compared to each operator procuring these individually. The management contractor would assume responsibility for the emergency preparedness program, leaving the operator free to concentrate on the business at hand and not on an event that may never occur. Operators could choose to participate only in regions in which they are active and in only those services they select (example, equipment would be available with or without operators).

As envisioned, cost of such a regional center located in Houston would break down as follows:

	Initial fixed cost ($1,000)	Monthly expenditure ($1,000)
Yard operation	$227.5	$101.5
Equipment	4,718.1	115.0
Coop. administration	14.0	11.0
Database	14.1	3.5
Contingency planning	250.0	25.0
Response drill and eq. testing	0.0	1.6
R & D	0.0	83.3
New equipment	0.0	83.3
Totals	**$5,223.7**	**$424.2**